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Republic of South Africa
Department of Industries
Sea Fisheries Branch

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CONTRIBUTIONS TO OCEANOGRAPHY AND FISHERIES BIOLOGY

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1977

THE FEASIBILITY OF COMMERCIAL EXPLOITATION OF A BLACK MUSSEL POPULATION NEAR HERMANUS, SOUTH AFRICA

G. DE VILLIERS

Several applications for the commercial exploitation of black mussels from intertidal beds prompted a survey of the coastline near Hermanus (34°25′S; 19°15′E) to establish whether such exploitation on a small scale should be allowed for a test period. Only two consecutive days over a spring tide period in April 1976 were available for field work. One scientist and two assistants were involved. The survey was therefore conducted in a manner suitable for accumulating meaningful results quickly and with limited manpower.

THE SURVEY AREA

On the first day of the survey, the intertidal zone was inspected at several sites over a distance of 8 nautical miles between Sand Bay (near Onrus River mouth) and Die Polle (Fig. 1). The proposed exploitation area indicated by the local applicant, i.e. between Mussel River mouth and Grotto Beach (Fig. 1), was inspected along its entire length.

The coast to the west of the Mussel River mouth, which includes the old and new harbours, is a rugged rocky shore exposed to heavy swells. From Grotto Beach eastwards a sandy beach stretches over a distance of 7 nautical miles. In this region, only a few isolated and small rocky banks occur in the lower intertidal zone. The proposed exploitation area is situated between these two stretches of coastline and clearly represents a transition zone between the sandy and rocky shores. It is less exposed to heavy swells than the adjacent areas.

METHODS

Inspection of the survey area and consultation with the local entrepreneur were deemed essential for providing a sound background to the investigation. Also, three randomly selected samples of recently washed-up shells were collected to obtain an idea of the size composition of black mussels in different regions. In addition, three samples of living mussels were collected at the Mussel River mouth from the lower, intermediate and higher parts of the intertidal zone respectively. Each sample was taken from a dense mussel bed by removing all individuals from a completely covered rock surface area of 0,25 m².

The total surface area covered by black mussels could not be measured directly. Therefore, the requisites for calculating this were estimated. In an attempt to keep these estimates as objective as possible, the three observers on site firstly estimated the numerical value of one dimension independently. These different values were then discussed and, finally, an acceptable figure for that dimension was mutually agreed upon.

The process was repeated for all the parameters required. These included percentage cover, length and width of the distribution area and percentage of the entire population represented by the various samples.

OBSERVATIONS AND RESULTS

Two species of mussel, namely *Choromytilus meridionalis* (Kr.) and *Perna perna* (L.), were encountered on rocks in significant quantities. The latter occurred sparsely throughout the whole survey area but the former was restricted to rocks in close proximity to sand. The distribution of both species, particularly that of the former, was very patchy, so that rock surfaces were mostly either entirely covered in or entirely free of mussels.

It had been indicated that both species were suitable for exploitation, provided that individuals were at least 60–70 mm in length. Although the different species were therefore regarded as one stock for the purposes of the survey, it was quite clear that *Choromytilus* predominated in the proposed exploitation area. It did, in fact, constitute almost 100 per cent of individuals in the samples.

It was soon evident that mussels could not be

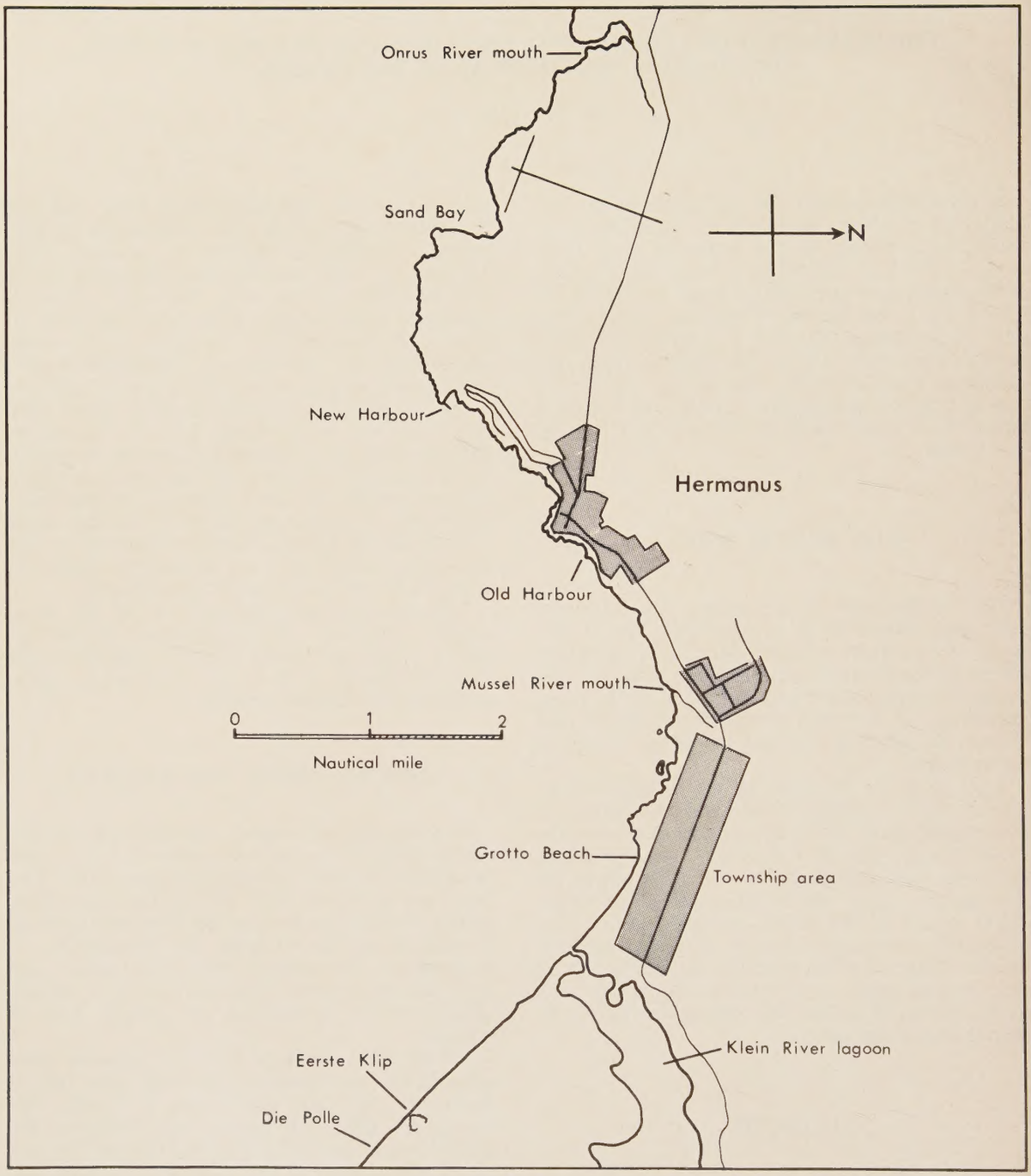

Fig. 1: The survey area

harvested economically west of the Mussel River mouth because of their small size, low distribution density and inaccessibility. The region to the east of Grotto Beach could also not be expected to yield a significant quantity, as rocks were few and inaccessible. Two samples of washed-up shells from this region (Table I – Eerste Klip and Die Polle) indicated that less than 5,5 per cent of the mussel population would be large enough for exploitation, i.e. 70 mm or more in length.

The total surface area entirely covered by black mussels in the region Grotto Beach to Mussel River mouth (Fig. 1) could be estimated by multiplying the total length of the coastline concerned by the average width of the distribution zone and by the average percentage of fully covered surface. Numerical estimates of these parameters were 2 000 m, 20 m and 3 per cent respectively. This yielded an estimated surface area of ± 1 200 m². The size composition and the average distribution density on these entirely covered surfaces were obtained from the three live samples collected at the Mussel River mouth by appropriate weighting of the data. It was estimated that samples from the lower, intermediate and higher parts represented 10, 45 and 45 per cent respectively of the total intertidal population. Therefore, both the sampled surface area and number of individuals per length class for each sample had to be multiplied by the respective percentages to arrive at the complete picture for the whole intertidal population. This is reflected in Table II.

From these calculations, the average packing density for entirely covered rocky surface was 28 415 black mussels per 25 m² (i.e. 100 x 0,25 m² – see also Table II), or 1 137 per square metre. The figure for individuals 70 mm and larger (i.e. 350 per 25 m² – Table II), multiplied by the total entirely covered surface area of 1 200 m², indicates an estimated standing crop of only 16 800 mussels available for exploitation. This estimate increases to 80 160 if the minimum size is lowered to 60 mm. The total intertidal population in this restricted area probably consists of approximately 1,36 million (i.e. 1 137 x 1 200) black mussels, excluding recruits less than 10 mm shell length, which were not sampled.

DISCUSSION AND CONCLUSIONS

Black mussels are seldom used for direct human consumption locally. Although their potential as an additional source of protein has long been realized, commercial exploitation of natural beds is not allowed for this purpose in South Africa. Along the West Coast, the reasons are, firstly, their importance as a food resource for the valuable rock-lobster stocks and secondly, the danger of shellfish poisoning that occurs occasionally after massive *Gonyaulax* blooms (Grindley and Nel 1970). However, as the rock-

Table I: Length composition of washed-up black mussel shells

Shell length (mm)	Number per length class		
	Die Polle	Eerste Klip	Mussel River
10 – 14	—	—	1
15 – 19	—	—	1
20 – 24	—	—	8
25 – 29	—	1	16
30 – 34	4	—	24
35 – 39	14	20	11
40 – 44	16	16	18
45 – 49	15	8	6
50 – 54	11	7	7
55 – 59	4	3	7
60 – 64	2	3	4
65 – 69	3	1	2
70 – 74	3	—	—
75 – 79	1	—	1
Total	73	59	106
Percentage 70 mm and longer	5,5	0,0	0,9

Table II: Length composition of the intertidal black mussel population at Mussel River mouth

Shell length (mm)	Number per length class			
	Lower sample (a)	Intermediate sample (b)	Higher sample (c)	Entire population (10a + 45b + 45c) *
10–14			60	2 700
15–19			169	7 605
20–24			159	7 155
25–29		1	65	2 970
30–34		2	46	2 160
35–39		6	9	675
40–44		2	13	675
45–49	1	3		145
50–54	1	27		1 225
55–59	4	31		1 435
60–64	2	18		830
65–69	4	10		490
70–74	7			70
75–79	5			50
80–84	12			120
85–89	5			50
90 +	6			60
Total	47	100	521	28 415

* It was estimated that samples (a), (b) and (c) represent approximately 10%, 45% and 45% of the total intertidal population respectively

lobster population is less important commercially and the incidence of such phytoplankton blooms less frequent east of Cape Point (Cape of Good Hope), it seems desirable that the natural black mussel stocks in that region be utilized to a greater extent. Additional motivation for a policy of commercial exploitation of these stocks emerges from the fact that recent South African mariculture experiments with *C. meridionalis* (Mostert 1972 and Du Plessis, in press) have not yet reached the stage where these animals can be supplied commercially. Commercial supplies of local black mussels are, in fact, at present non-existent while local demand is certainly increasing.

In order to interpret the results obtained during this survey correctly, it is necessary to gain insight into the likely rate of recruitment once exploitation commences.

Unfortunately, few references to growth and reproduction of natural *C. meridionalis* populations are available and only that of Griffiths (1976) relates to a stock east of Cape Point, i.e. to one in False Bay. Curry and Cook (1975) found that *C. meridionalis* along the West Coast may reach lengths of 45 mm (average for an intertidal population) to 61 mm (maximum for settlement on submerged asbestos plates) during the first year after settlement, while sexual maturity is attained at approximately 30 mm. Du Plessis (in press) reported even higher growth rates, i.e. 78 mm and 92 mm in length after the first and second year respectively, on suspended ropes in raft culture experiments, but Griffiths (*op. cit.*) observed growth rates of only 30 mm and 24 mm on intertidal beds during the first year along the West Coast and in False Bay respectively.

Larval settlement may occur throughout the year along the West Coast but appears to be scanty during winter and early spring. It takes place 31 – 60 days after spawning (Du Plessis, in press). Griffiths (1976) reported a peak spawning period lasting from September to February in False Bay, whereas gonads are inactive during April, May and June. She found that settlement was erratic.

In conclusion, it appears that an extremely high recruitment rate could be possible, although the incidence and magnitude of resettlement and the natural mortality rate on exploited beds remain unknown factors.

If it is assumed, however, that the current stock is an accumulated one and that recruitment to the proposed exploitable proportion could hardly exceed 50 per cent of the standing crop per year, the population still remains inadequate for commercial exploitation, even if a

minimum size of 60 mm is accepted. Also, this is the only source of black mussels easily accessible to the general public along a fairly long stretch of coastline and the region is frequently visited by the general public for recreational purposes, as it is situated in a residential area. For a combination of these reasons, it appeared advisable not to allow commercial exploitation of the investigated stock.

From the survey results, it seems likely that *Choromytilus meridionalis* may occur in dense concentrations in other places between Cape Point and Cape Agulhas where sandy and rocky shores meet, e.g. at Kleinmond, Hawston, Uilkraal River mouth, Pearly Beach etc. It is, however, also likely that commercial exploitation in these regions would not be feasible for the same reasons as in the case of Hermanus.

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AN IMPROVED TECHNIQUE FOR SUBSAMPLING EGGS FOR FECUNDITY STUDIES

A. P. VAN DALSEN

Fecundity studies on the snoek, *Thyrsites atun* Euphrasen, initially made use of the dry weight method, which involved counting the number of eggs (oocytes) in a subsample of the whole dried ovary. However, snoek roes being large (½ – 4 million eggs) require up to a week of drying time before the mass becomes constant and also moisture is often absorbed from the air during the actual weighing.

Thus, a quick, reliable sampling technique was devised, based on the method of Cassie (1956). The same basic method of negative pressure was employed, but the new apparatus was more durable, easier to use and automatically drew up the same constant subsample.

Eggs of the Cape harder *Mugil richardsoni* were also used to test the apparatus.

MATERIAL AND METHODS

Description of apparatus

The volumetric subsampler (Fig. 1) consists of a 20-ml pipette (B) with its nozzle cut off at the point where the tube narrows. This facilitates free passage of the eggs into the pipette. The cut edge is ground smooth and the pipette clamped to the one arm of a Fischer burette stand (A).

A rubber bulb (C), approximately half filled with water, is connected to the lower end of a glass tube (D) about 24 cm in length. This tube has the same internal diameter as the pipette, is clamped to the other arm of the stand and is inserted half-way into the neck of the bulb, allowing air bubbles to escape on squeezing the bulb.

A two-way stop-cock (E) is attached by means of a short, thick rubber tube (G) to the upper end of the glass tube. The walls of the rubber tube are 5mm thick. An L-shaped glass tube (F), with the same diameter as the rest of the glass tubing, connects the pipette to the stop-cock. Thick rubber tubing (G) is again used at each end of this L-shaped tube.

A 2 000-ml glass beaker (I) containing the sample of eggs (J) and agitator beads (K) is placed on a Heidolph variable-speed magnetic stirrer (H). The direction of stirring alternates every 15 seconds causing a thorough agitation of the bulk egg sample.

A 50-ml measuring cylinder is used to catch, measure and transfer the subsample.

If the egg sample is small, a 10-ml pipette and 1 000-ml glass beaker may be substituted.

Calibration of subsampler

In order to acquire a constant subsample volume automatically, a reference mark (a) was first established approximately midway up the glass tube (D). To do this, the end of the pipette was immersed in a container of water and the two-way stop-cock, communicating between the rubber bulb and the pipette, opened. The bulb was squeezed until the meniscus in the pipette tube was flush with the bottom end of the pipette. The stop-cock was then closed. Any drops of water stuck on the inside walls of the pipette were eliminated by gentle tapping.

The first trial position (a_1) was marked with a felt-tip pen half-way up the glass tube (D). The stop-cock communicating between the bulb and the atmosphere was then opened and the bulb squeezed. This raised the water level in the tube beyond the first trial position (a_1). The stop-cock was then closed and the neck of the bulb squeezed to remove the air bubbles. The stop-cock was gently opened until the meniscus was on the mark, thus creating a negative pressure in the bulb.

The stop-cock communicating between the bulb and the pipette was now slowly opened. The water flowed into the pipette owing to the negative pressure until equilibrium was reached. The position of the meniscus was noted. If it was not on the 20-ml graduation mark (b), the first trial position (a_1) was replaced with a second trial position (a_2) at a point approximately equal to the difference between the meniscus and the graduation mark on the pipette.

The whole operation was repeated, several times if necessary, until the exact reference line (a) was established. The meniscus was then level with the 20-ml graduation mark (b) on the pipette. A 50-ml graduated flask was placed under the pipette and the subsample water allowed to flow into the flask. The volume was noted. (As a result of the nozzle of the pipette

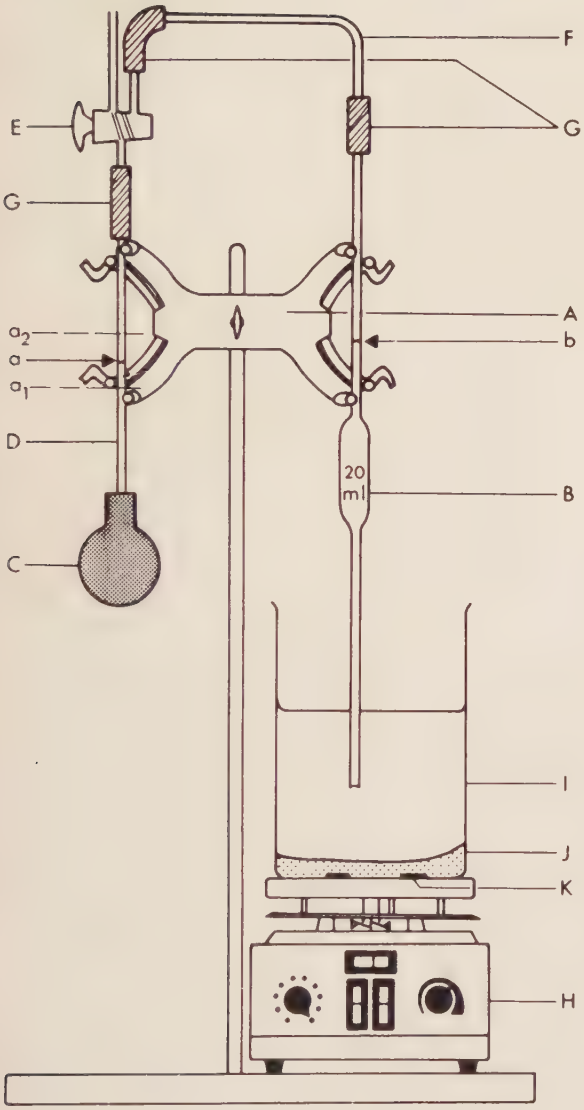

Fig. 1: Details of volumetric subsampler

having been removed, the subsample volume was slightly less than 20 ml). A slight variation in subsample volume was evident but the mean of all subsamples was accepted as the constant.

Subsampling technique

The sample of eggs was separated using Gilson's fluid (as modified by Simpson 1951), cleaned by washing with water and placed in a 2 000-ml glass beaker. Tap water was added to bring the volume up to 1 250 ml (or any other predetermined volume) and the sample placed on the magnetic stirrer. The end of the pipette was immersed midway into the sample and slightly away from the sides of the beaker, and the stirrer beads were dropped in.

Before siphoning the subsample, the stirrer was set in motion and the speed adjusted until the sample was thoroughly agitated. Experience showed that the best mixed state was obtained when the mass of eggs was pushed up to a point just beneath the surface of the liquid immediately before the whirlpool started. The stop-cock was opened and a subsample drawn into the pipette. Once equilibrium had been reached the stop-cock was quickly shut off and the beaker carefully but quickly removed (for this purpose, the magnetic stirrer was first shifted). Speed was important to prevent the eggs from settling and dropping away from the pipette tube. The subsample was poured into the measuring cylinder and any eggs remaining in the pipette were washed in also. Periodic washing of the pipette was essential to prevent eggs and water drops sticking to its inside walls.

When making preparations for subsampling it was found necessary to check beforehand that the meniscus in the pipette rose to the 20 ml graduation mark. Sometimes it varied owing either to slight evaporation of the water in the rubber bulb or to fluctuation in barometric pressure.

A counting maze was used to determine the number of eggs in the subsample.

The total number of eggs in the sample was calculated (after Cassie 1956) as:

$$N = \frac{1\,250n}{v}$$

where n = total egg count of all subsamples
v = total volume of subsample (ml).

At the completion of subsampling, tap water was drawn into the pipette and the apparatus stored with the stop-cock closed completely.

RESULTS

Tests with snoek eggs

New apparatus – Extensive tests were carried

out on the apparatus using snoek eggs. One bulk sample of separated clean eggs was used throughout. Ten subsamples were taken with the pipette placed at different positions in the beaker of eggs. The positions were:

S = side of beaker
C = centre of beaker
M = half-way between side and centre of beaker
$\frac{T}{M}$ = near the surface, half-way between the side and the centre of the beaker
$\frac{T}{C}$ = near the surface, at the centre of the beaker
$\frac{T}{S}$ = near the surface, at the side of the beaker
$\frac{L}{S}$ = near the bottom of the beaker, at the side
$\frac{L}{M}$ = near the bottom of the beaker, half-way between the side and the centre
$\frac{L}{C}$ = near the bottom of the beaker, at the centre.

Estimates of the number of eggs in the bulk sample, based on the subsamples from the nine different positions, are given in Table I. The mean value was 654 124, the coefficient of variation (SD/mean) being 1,7 per cent and the deviation from the mean, less than 5 per cent in all cases (Fig. 2a).

The density distribution of the snoek eggs taken at the time of subsampling was drawn graphically, using the data from Table I (Fig. 2b). The dark-shaded areas fell within 1 per cent and the light-shaded areas within 5 per cent of the mean. An accurate subsample could thus be drawn from anywhere in the beaker.

Because of the whirlpool action, one further count was made just beneath the surface at the centre to establish if any serious fluctuations occurred in these counts compared with those of samples taken at other positions. The fluctuations proved to be negligible.

Dry weight method – The subsample count from position 9 (Table I) was retained for estimating the number of eggs using the dry weight method in an attempt to compare these two methods. The subsample count was 10 280 eggs.

Both subsample and bulk sample were partially dried by vacuum filtration through coarse, dry filter paper and placed in a dessicator for an hour before determining the mass. After filtration, the eggs plus filter paper were transferred to large petri-dishes and dried at 60°C for 60 hours. (A higher temperature would have resulted in a burning out of natural oils.) After removal from the oven, the eggs were transferred to a dessicator and allowed to stand for two hours to cool. To minimize the absorption of moisture by the eggs, their masses were immediately determined to the nearest 0,0001 g. The total number of eggs in the sample was calculated as 659 206, comparing favourably with the estimates using the subsampler (Fig. 2a).

Table I: Comparison of egg counts at various positions in the sample

Sample number	Position in beaker	Total number of eggs estimated
1	S	658 974
2	C	665 897
3	M	674 038
4	$\frac{T}{M}$	650 769
5	$\frac{T}{C}$	644 038
–*	$\frac{T}{C}$	645 000
6	$\frac{T}{S}$	647 564
7	$\frac{L}{S}$	654 551
8	$\frac{L}{M}$	653 526
9	$\frac{L}{C}$	637 756
Mean ($\bar{x}$)		654 124
Standard deviation (SD)		11 085
Number (N)		9

* Not used for determining mean and standard deviation

Tests with Cape harder eggs

In an attempt to confirm the reliability of the new apparatus, further tests were carried out on a sample of eggs from the Cape harder or mullet, *Mugil richardsoni*. Fifteen counts were made, the extra six counts being derived from between D and E of Figure 3b. Deviation in this test again fell within 5 per cent of the mean, except for one reading taken at the top centre of the beaker (Fig. 3a).

Figure 3b shows a favourable density distribution pattern for these 15 counts, indicating that harder eggs can also be successfully subsampled anywhere in the beaker.

DISCUSSION

It is apparent that the subsampling technique described here has certain advantages over the

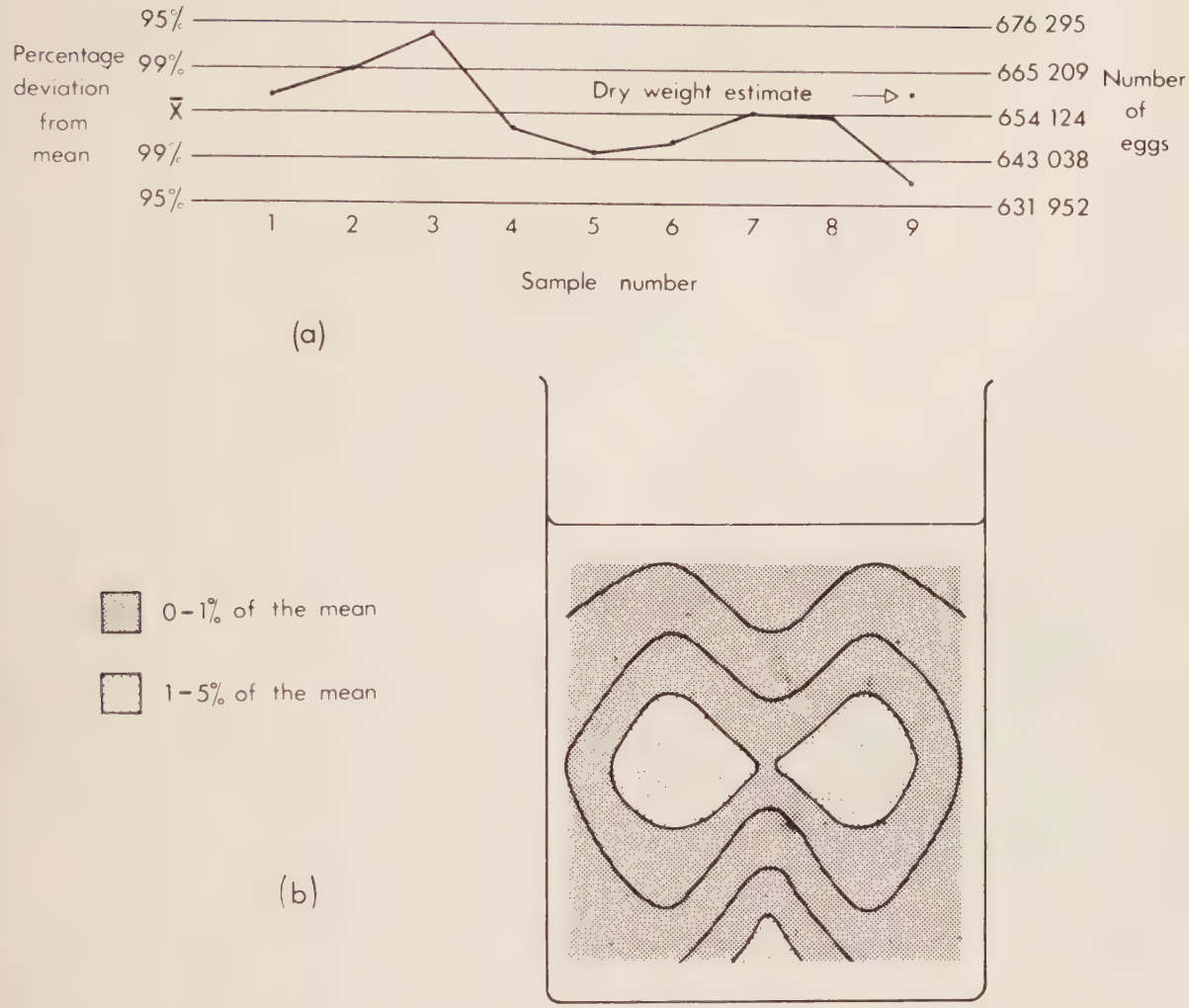

Fig. 2: Density distribution of snoek eggs at the time of subsampling

dry weight method previously employed in snoek research although giving comparable results. The new technique took less time, allowing at least one sample to be handled per day.

May (1967) compared the results of the "whirling-vessel" method (as modified by Pitt 1965) with those of the dry weight method. The coefficient of variation for the whirling-vessel method was 6,0 per cent and for the dry weight method, 3,1 per cent. Thus, the new method (coefficient of variation 1,7 per cent) was shown to be more accurate than either of these two methods.

The apparatus described here has the benefit of simplicity and ease of manipulation in comparison with that of Cassie (1956).

The ability to control the drawing in of eggs by manipulating the stop-cock only at that critical point when the eggs are thoroughly agitated, resulting in a smoothly controlled, fixed volume of eggs, gives the method an obvious advantage over the "sawn off" pipette fitted with a rubber bulb and squeezed by hand, an erratic method still commonly in use for subsampling plankton.

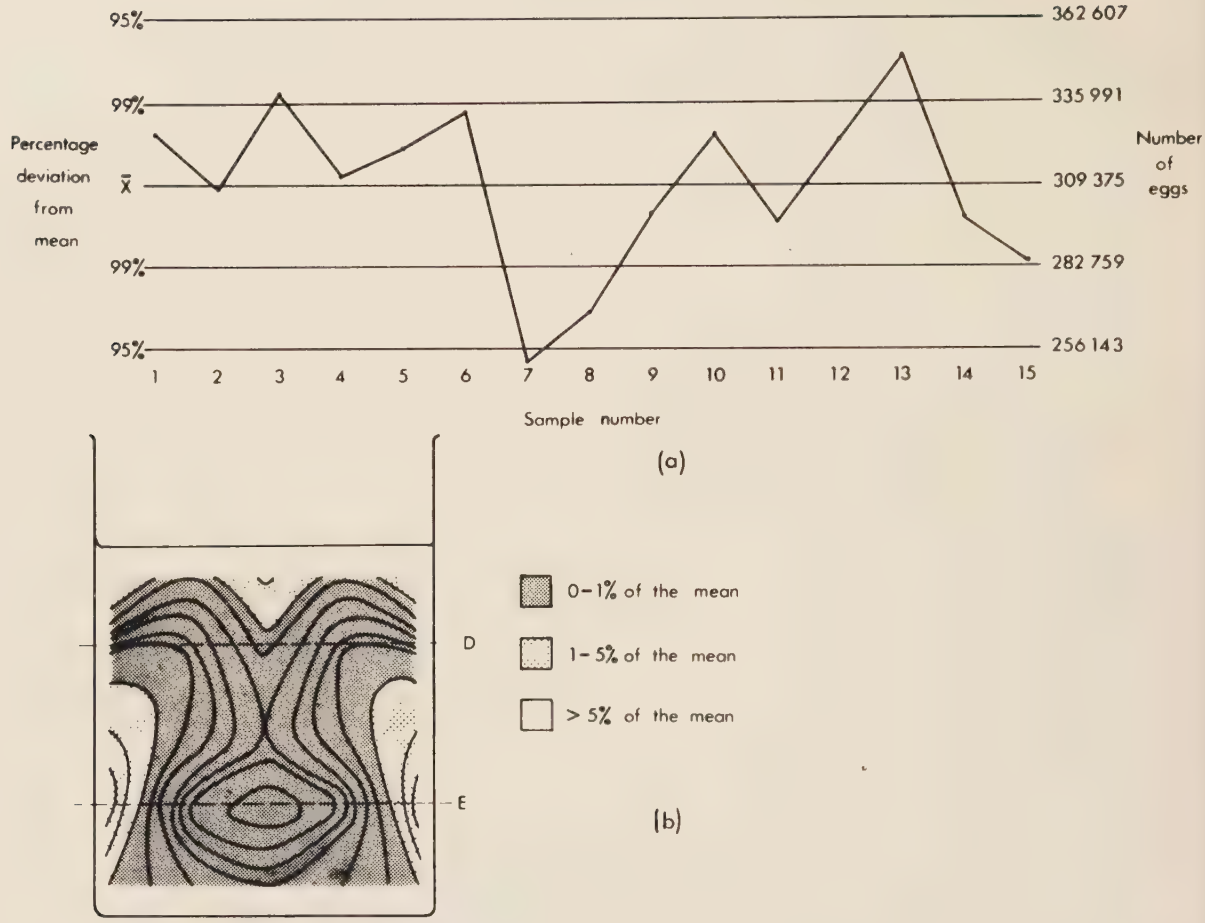

Fig. 3: Density distribution of harder eggs at the time of subsampling

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A COMPARISON OF FOUR METHODS USED IN FECUNDITY DETERMINATION OF THE PILCHARD *SARDINOPS OCELLATA*

F. LE CLUS

Fish fecundity has been estimated by both gravimetric and volumetric methods, but automatic egg counters (Broad 1955, Parrish *et al.* 1960, Davis and Paulik 1965) and manual counting (Rounsefell 1957, Staples 1975) have also been used.

Gravimetric methods were used by MacGregor (1957), May (1967), Zijlstra (1973), Burd and Howlett (1974) and Healey and Nicol (1975) either with the complete ovaries or the separated oocytes. The mass of the oocytes was determined either after partial drying with a vacuum pump or after total drying. Volumetric methods are dependent upon the separation of the ovarian tissue from the oocytes. Subsamples have been obtained by various methods including whirling vessels (Pitt 1965, May 1967) and Stempel pipettes (Simpson 1951, Dias *et al.* 1973).

In this study, four methods were compared to find the most efficient and practical method of fecundity estimation. Two were based on gravimetric and two on volumetric techniques.

DESCRIPTION OF METHODS

General procedure

Female pilchards, *Sardinops ocellata* Pappe, were obtained from commercial catches landed at Walvis Bay.

Both ovaries from each fish were slit open and preserved in Gilson's fluid (as modified by Simpson 1951). Gilson's fluid is a fixative and a preservative and has been used on both fresh and preserved ovaries from a wide range of species, e.g. *Sardina pilchardus* (Dias *et al.* 1973), *Hippoglossoides platessoides* (Bagenal 1957), *Pleuronectes platessa* (Simpson 1951), *Harengula jaguana* (Martinez and Houde 1975), *Scophthalmus maximus* (Jones 1974), *Coregonus clupeaformis* (Healey and Nicol 1975) and *Clupea harengus* (Zijlstra 1973, Burd and Howlett 1974). It hardens and preserves oocytes while liberating them by breaking down ovarian tissue. Repeated shaking facilitates separation. After 3–6 weeks, the Gilson's fluid was replaced by 5 per cent formalin, because oocytes left in the fluid for more than 8 weeks were found to be in poor condition.

The oocytes were placed in a sample tube and agitated by several jets of water from a wide-mouthed glass dropper. When they were randomly distributed in the water column, a dropper was used to remove a subsample from the middle of the sample. This subsample was then placed in the narrow groove of a counting tray. The diameters of the oocytes were measured by means of a micrometer fitted to a binocular microscope of ×80 magnification. The method devised by Clark (1934), which entails measurement in one plane only, was found to be completely satisfactory. In order to obtain an even distribution, 150–200 oocytes were measured at intervals of 63,5 µm.

Although there were normally several discrete size groups of oocytes in an ovary, it was found that only the two groups of oocytes with larger diameters were yolked. The modes of these two groups were obtained separately: the size group with larger yolked oocytes was referred to as last-mode oocytes and the smaller group as intermediate-mode oocytes. The number of oocytes in each mode was ascertained from subsamples and the numerical ratio between the modes determined.

Ovarian tissue was removed at this stage by means of Endocott sieves. Appropriate sieves were used to separate the last-mode from the intermediate-mode oocytes. Only the last-mode oocytes could be used for actual determination of number as some tissue was invariably retained with those of the intermediate mode.

Volumetric-A and gravimetric-A methods

Three subsamples were removed with a wide-mouthed dropper, counted in a Z-counting tray and stored in separate tubes. A modified Yashnov apparatus was used for the volumetric determination (Robertson 1970). The preserved oocytes were cleaned and the excess deionized water removed by means of a vacuum pump.

The mass of these relatively dry oocytes was determined to the nearest 0,01 g, and the volume to the nearest 0,01 mm^3 by means of a piston burette. This procedure was repeated three times both for each subsample and for the remainder of the sample. From the values obtained the number of last-mode oocytes was calculated.

Volumetric-B method

This method was found to be much quicker than the previous two methods, yet gave comparable results.

The total volume of all the last-mode oocytes for each fish was measured according to the volumetric-A method and divided by the mean oocyte volume to give the total number of last-mode oocytes.

Gravimetric-B method

The previous three methods were based on the assumption that all the ovarian tissue had been removed; any residual fine tissue would have caused an overestimation of the number of oocytes. The gravimetric-B method is an adaptation of the gravimetric-A method, but the number of oocytes can be estimated at almost any early stage of development, once the oocyte modes can be distinguished readily. Last-mode oocytes may either be separated from the intermediate-mode oocytes or they may be treated together, depending upon the developmental stage.

The preparation of the gonads was the same as for the gravimetric-A method. After the oocytes had been cleaned with deionized water in the Yashnov apparatus, the lower half of the apparatus was replaced and water added, thus allowing free movement of the oocytes during mixing. The oocytes were agitated as for the previous methods and the lower half of the apparatus quickly removed to allow the water to drain away. The oocytes were vacuum dried and the mass determined to an accuracy of 0,1 mg. Three small subsamples of about 100 mg each were removed and, after the mass had been determined to the nearest 0,1 mg, were stored in separate sample tubes. The number of oocytes in the subsamples was counted and the total number of oocytes in the original sample calculated.

A different sample of 15 fish in a less advanced stage of development was used for this method. Thus, a direct comparison with the previous three methods was not possible.

EVALUATION OF THE METHODS

Relative fecundity was used instead of absolute fecundity, thus excluding as far as possible the effects of differences in the length of the fish. The relative fecundity was calculated as the number of oocytes per unit average body mass. The average body mass was calculated from pilchard data collected over a period of 15 years from fish landed at Walvis Bay (H. J. Smit, Sea Fisheries Branch, unpublished data).

The precision of the gravimetric-A, volumetric-A and gravimetric-B methods was established by means of one-way analysis of variance. Three relative fecundity values obtained for each fish (Table I) were used to estimate the error of the method. An unbiased estimate of the variance in relative fecundity between fish was found by subtracting the variance within fish from the variance between fish and dividing by the number of subsamples (Snedecor and Cochran 1967). This adapted variance was still much higher than the variance due to error in the methods. The r–values of 0,9729, 0,9346 and 0,9670 showed that the error in the method did not significantly affect the variance between fish. The coefficient of variation expressed as a percentage was lowest for the gravimetric-B method and highest for the volumetric-A method (Table I).

For the volumetric-B method, the variance inherent in the method was determined from the oocytes of one fish only to exclude the effect of variance between fish. Ten estimates were obtained of the total oocyte volume and of the mean volume per oocyte. The coefficient of variation for total oocyte volume was 2,32 percent and for mean oocyte volume, 4,64 per cent. A K-by-K table was used to obtain 100 possible estimates of absolute fecundity from these values, absolute fecundity being calculated from the total volume of the oocytes divided by mean oocyte volume. The coefficient of variation for absolute fecundity was 4,98 per cent (Table II).

The accuracy of the volumetric-B method was established by comparing absolute fecundity values obtained by manual count with values estimated by means of the method (Table III). In most cases the method slightly underesti-

Table I: Analysis of variance for the gravimetric-A, volumetric-A and gravimetric-B methods

Method	Gravimetric-A		Volumetric-A		Gravimetric-B	
Source of variation	Between fish	Within fish	Between fish	Within fish	Between fish	Within fish
Degrees of freedom	23	48	23	48	14	30
Mean sum of squares (σ^2)	22 558	207	17 882	408	26 180	295
**Adapted sum of squares ($\tilde{\sigma}_B^2$)	7 450		5 825		8 629	
*Variation ratio ($\tilde{\sigma}_B^2/\sigma_W^2$)	36		14		89	
$r = \tilde{\sigma}_B^2/(\sigma_B^2 + \sigma_W^2)$	0,9729		0,9346		0,9670	
Coefficient of variation of method	6,55%		9,64%		4,39%	

*B = between fish, W = within fish **$\tilde{\sigma}_B^2 = \frac{(\sigma_B^2 - \sigma_W^2)}{3}$

Table II: Coefficient of variation of the error in the volumetric-B method of fecundity estimation

Source	Mean	Standard deviation	Coefficient of variation (%)
Total oocyte volume (T)	7 126 mm³	165,2 mm³	2,32
Mean oocyte volume (V)	0,1831 mm³	0,0085 mm³	4,64
Absolute fecundity (T/V)	39 008 oocytes	1 941,35 oocytes	4,98

mated the fecundity. The difference between the means was 1,50 per cent. This value was used to establish the accuracy of the gravimetric-A and volumetric-A methods. The volumetric-B method was employed to estimate the fecundity of the same 24 fish used for the gravimetric-A and volumetric-A methods. The mean relative fecundity estimated by this method was 222,7 oocytes per gram body mass. By adding 1,50 per cent to this, the "actual" fecundity was found to be 226,0 oocytes per gram body mass. The gravimetric-A method overestimated this value by 1,28 per cent and the volumetric-A method underestimated it by 8,18 per cent. The accuracy of the gravimetric-B method was not established.

Table III: Comparison between the absolute fecundity obtained by manual count and volumetric estimation

Fish number	Manual count	Volumetric estimate
1	31 520	30 424
2	29 376	30 191
3	36 291	34 819
4	35 258	34 911
5	34 398	33 810
6	27 635	27 388
Mean	32 413	31 924

DISCUSSION

Fecundity determination can be made at any stage prior to spawning, provided the oocytes to be spawned have separated from the general oocyte stock. However, accuracy is greater at the active-ripe stage when the oocytes are large enough to be easily handled. Once the oocytes are ripe, some may be lost owing to pressure on the gonads when the fish are caught.

Table IV lists the precision obtained in the different methods used for fecundity determination by various authors. The degree of precision expressed as coefficient of variation ranged between one and ten per cent.

The automatic egg counter used by Parrish *et al.* (1960) gave a maximum discrepancy between counts and a maximum error between known samples of less than 1,0 per cent. Zijlstra (1973) compared the accuracy of the volumetric method (Simpson 1951) with that of Polder and Zijlstra (1959) and that of Parrish *et al. (op. cit.)*. Polder and Zijlstra (1959, quoted from Zijlstra 1973) blotted the surface of the whole wet ovary, determined the total mass and the mass of two to five subsamples and counted the oocytes in the subsamples. McGregor (1922, quoted from Bagenal and Braum 1968) claimed

Table IV: The precision of different methods of fecundity determination

Authority	State of oocytes	Method used	Coefficient of variation (%)		
			Single counts	Multiple counts	Number of subsamples
McGregor 1922 (quoted by Bagenal and Braum 1968)	Wet	Gravimetric		1,0	2
Simpson 1951	Wet	Volumetric	9,6	3,6	4
Bagenal 1957	Wet	Volumetric	10,1	5,0	4
Kändler and Pirwitz 1957 (quoted by Kändler and Dutt 1958)	Wet	Volumetric		3,8 – 4,5	4
Simpson 1959 (quoted by Bagenal and Braum 1968)	Dry	Gravimetric		±3,0	2
Parrish *et al.* 1960	Wet	Automatic		1,0	3
Davis and Paulik 1965	Wet	Automatic	<1,0		
Zijlstra 1973	Wet	Volumetric		5,0 – 6,0 *	2–5
Zijlstra 1973	Wet	Gravimetric		5,0 – 6,0 *	2–5
Zijlstra 1973	Wet	Automatic		5,0 – 6,0 *	2–5
Martinez and Houde 1975	Wet	Gravimetric		10,0	3
Healey and Nicol 1975	Dry	Gravimetric	±2,0		
Healey and Nicol 1975	Wet	Gravimetric	10,0		
Healey and Nicol 1975	Wet	Volumetric	10,0		

* 95 per cent confidence limit

that this method gave an answer within 1,0 per cent of the mean. Zijlstra (1973) found that the precision of the three methods, as estimated from the variance of two to five subsample counts and double counts on the egg counter, varied only slightly. The 95 per cent confidence limits in the fecundity estimates were in all three cases 5–6 per cent of the mean. He also found the egg counter techniques to be more time-consuming than the other methods.

Gravimetric methods on totally dry oocytes have been used for some species and coefficients of variation of about 2,0 per cent (Healey and Nicol 1975) and 3,0 per cent (Simpson 1959, quoted from Bagenal and Braum 1968) have been obtained. The small mass of totally dry pilchard oocytes precluded the use of this method in the present study. The dry oocytes were also extremely brittle in the more advanced stages of development.

From an analysis of the precision and accuracy of the four described methods, it appeared that the gravimetric-A and volumetric-B methods were equally accurate. The volumetric-B and gravimetric-B methods were more precise than the other two methods but the volumetric-B method was proved to be the shorter method where oocyte size is a requisite of the study.

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1977

EARLY DEVELOPMENT OF THE SOUTH AFRICAN MAASBANKER *TRACHURUS TRACHURUS* AT CONTROLLED TEMPERATURES

D. P. F. KING, M. J. O'TOOLE and A. A. ROBERTSON

The maasbanker or horse mackerel, *Trachurus trachurus* L., is a widely distributed fish which, in southern Africa, is abundant off the west and south coasts. It is of considerable economic importance and is exploited by both local and foreign purse seiners and trawlers.

In Cape waters, pelagic landings of maasbanker gradually declined from 100 963 metric tons in 1951 to 1 616 metric tons in 1974 (Sea Fisheries Branch, Annual Reports). In contrast, the total catches off South West Africa have increased, 63 000 metric tons being landed in 1968 and 250 000 metric tons in 1974 (F.A.O. 1974).

The population biology of the maasbanker has been the subject of a number of investigations in the past (Davies 1957, Komarov 1964, Geldenhuys 1973). However, little is known about its early life history in southern Africa. Haigh (1972) described the development of the larvae and the juveniles, but there is no description of the egg development or of newly hatched larvae in the literature. The eggs and the larvae of the same species in the Northern Hemisphere have been described by Ehrenbaum (1909) and Kiliachenkova (1970).

The incubation period of the egg in relation to temperature is unknown. A knowledge of egg developmental rate is an important criterion in determining the degree of spawning and the survival rate of eggs.

MATERIAL AND METHODS

Maasbanker eggs were collected from the Sea Fisheries Branch research vessel *Benguela* at 19h00 on 10 March 1976, approximately 7 km north-east of Cape Point (Fig. 1). Collections were made at the surface using paired Bongo nets (57 cm mouth diameter, 0,500 mm mesh). The sea surface temperature was 16,0°C at the time of sampling. Immediately after the haul, eggs were extracted from the sample and separated into various developmental stages of which the blastodisc stage was the youngest collected. A stereoscopic microscope with magnification ×20 was used for this purpose. Two or three eggs of the blastodisc stage were transferred to a series of incubation tubes each containing 100 ml of filtered sea water and the tubes were placed in a temperature-gradient block incubator as described by King (1975).

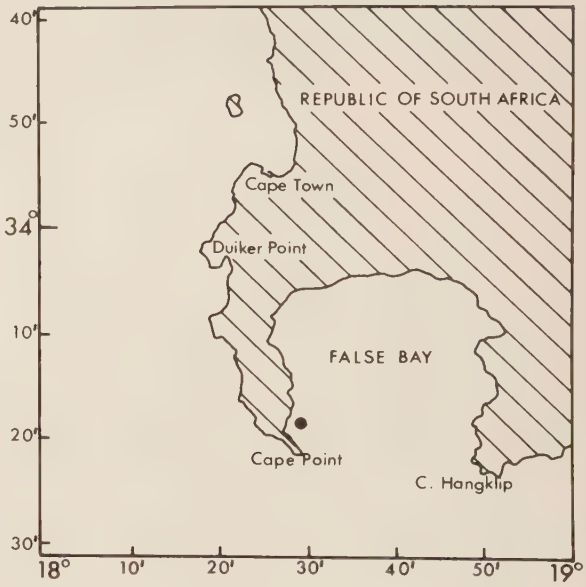

Fig. 1: The Cape Peninsula showing location of egg collection

Ten different constant temperatures, ranging from 12,6°C to 24,3°C, were employed during the experiment, each being monitored hourly with a 12-channel scanning thermistor recorder. Tests showed that, during incubation, temperature fluctuation within each row of tubes was minimal (Table I).

Observations on egg development were made every 2–6 hours depending upon the stage of the embryo. Each egg was removed from the incubator tube, placed in a petri-dish of filtered

Table I: Mean temperature and standard deviation for each row of incubation tubes

Row number	Mean temperature (°C)	SD
1	24,25	0,05
2	22,94	0,05
3	21,74	0,05
4	20,74	0,11
5	19,24	0,09
6	17,62	0,10
7	16,60	0,10
8	15,24	0,19
9	13,77	0,19
10	12,58	0,31

sea water of the same temperature, briefly examined and returned to the appropriate tube. Newly hatched larvae were measured from the tip of the snout to the end of the notochord. Prior to examination, the larvae were anaesthetized with MS 222 at a concentration of 1 : 20 000. After initial measurement, the larvae were examined daily until jaw formation and eye pigmentation were complete.

RESULTS

Description of the egg

The egg of the maasbanker is smooth, spherical, medium in size and has a single, fairly large oil globule. The mean diameter of 75 eggs was 0,91 mm (range 0,85–0,95 mm). The oil globule is yellow and positioned at the vegetative pole. The diameter ranged from 0,20 mm to 0,27 mm with a mean of 0,22 mm. The yolk is segmented and averaged 0,78 mm in diameter (0,65–0,87 mm). The mean width of the perivitelline space was 0,082 mm.

Developmental stages of the egg

Maasbanker eggs at various stages of development are illustrated in Figure 2 and the stages can briefly be described as follows:

Blastula (Stage 1) – from fertilization until the point at which the germ ring reaches the equator.

Gastrulation (Stage 2) – from the end of the blastula stage to blastopore closure. During the initial development, the germ ring begins to move around the blastodisc until it has completely surrounded the margin of the blastoderm. At the end of this stage, the embryonic axis is clearly visible and the optic vesicles are present but not completely formed. The developing embryo lacks pigmentation and the oil globule is at the periphery of the yolk in a median position.

Tail separation (Stage 3) – from blastopore closure to separation of the tail bud from the yolk. The tail bud becomes free from the yolk shortly after the blastopore closes and also after a number of pigment spots appear on the underside of the oil globule. Pigmentation of the embryo at this stage consists of a double row of small dendritic melanophores along the dorsal surface on each side of the notochord, some of which migrate ventrally. The row of pigment spots extends from behind the eyes to the caudal region but the tail itself lacks pigmentation.

Heart functioning (Stage 4) – As the body elongates, the tail begins to curl around the yolk and the fin fold develops. At the beginning of this stage, the heart starts to beat and scattered melanophores migrate ventrally along the lateral surface of the embryo in the mid and posterior regions. The two rows of melanophores, viewed dorsally, form a characteristic arch on the cranial region.

Hatching (Stage 5) – The embryo increases in length and encircles the yolk. The fin fold deepens and becomes lightly pigmented anteriorly. Approximately 15–18 myomeres can be counted. Movement of the embryo can frequently be observed.

Embryonic development rates

Observations of the incubation stages following Stage 1 (blastula) were recorded against time and the maximum duration of each morphological stage at the 10 incubation temperatures was obtained. The mean incubation time for each stage was plotted against temperature (Fig. 3) and regression lines fitted using the expression $y = ax^b$, where y = incubation time (hours), x = temperature (°C), and a and b are constants. The regression formulae were calculated from the individual observations rather

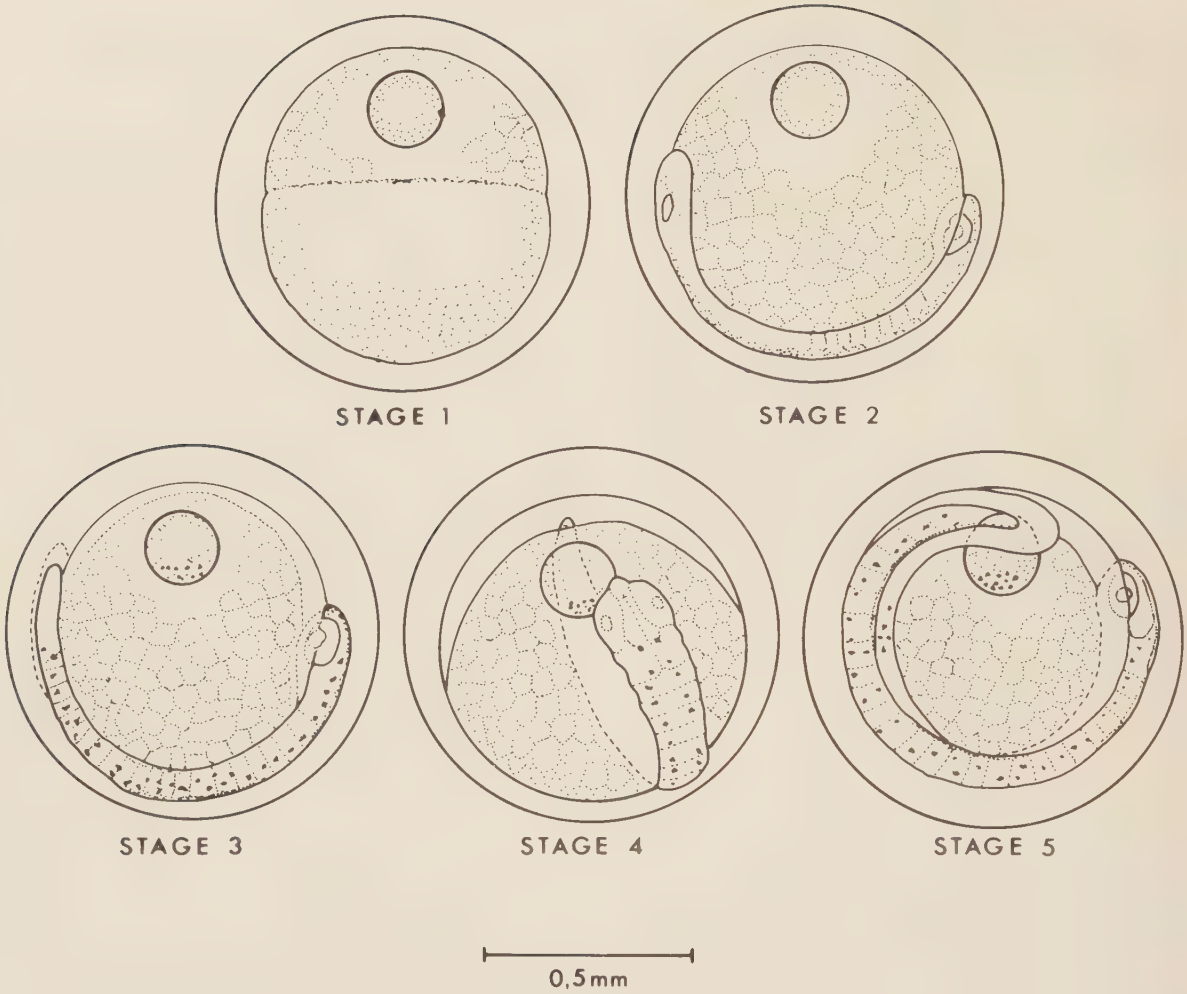

Fig. 2: Egg development of the maasbanker *Trachurus trachurus*

than from the means of the grouped data and are shown in Table II.

Table II: Correlation between temperature and incubation time for developmental stages 2–5

Stage	Regression formula
2	$y = 2134420{,}70\ x^{-4{,}23}$
3	$y = 14782{,}31\ x^{-2{,}22}$
4	$y = 26422{,}01\ x^{-2{,}38}$
5	$y = 22034{,}22\ x^{-2{,}19}$

y = incubation time (hours)
x = temperature (°C)

The incubation time to any given developmental stage decreased exponentially with increasing temperature. At the lowest and highest incubation temperatures (12,6°C and 24,3°C), complete gastrulation (Stage 2) required 36 hours and 2 hours respectively and the period to hatching (Stages 2–4), 84 hours and 20 hours respectively.

Description of the larva

Newly hatched larvae measure between 2,40 mm and 3,10 mm (mean 2,72 mm) and the

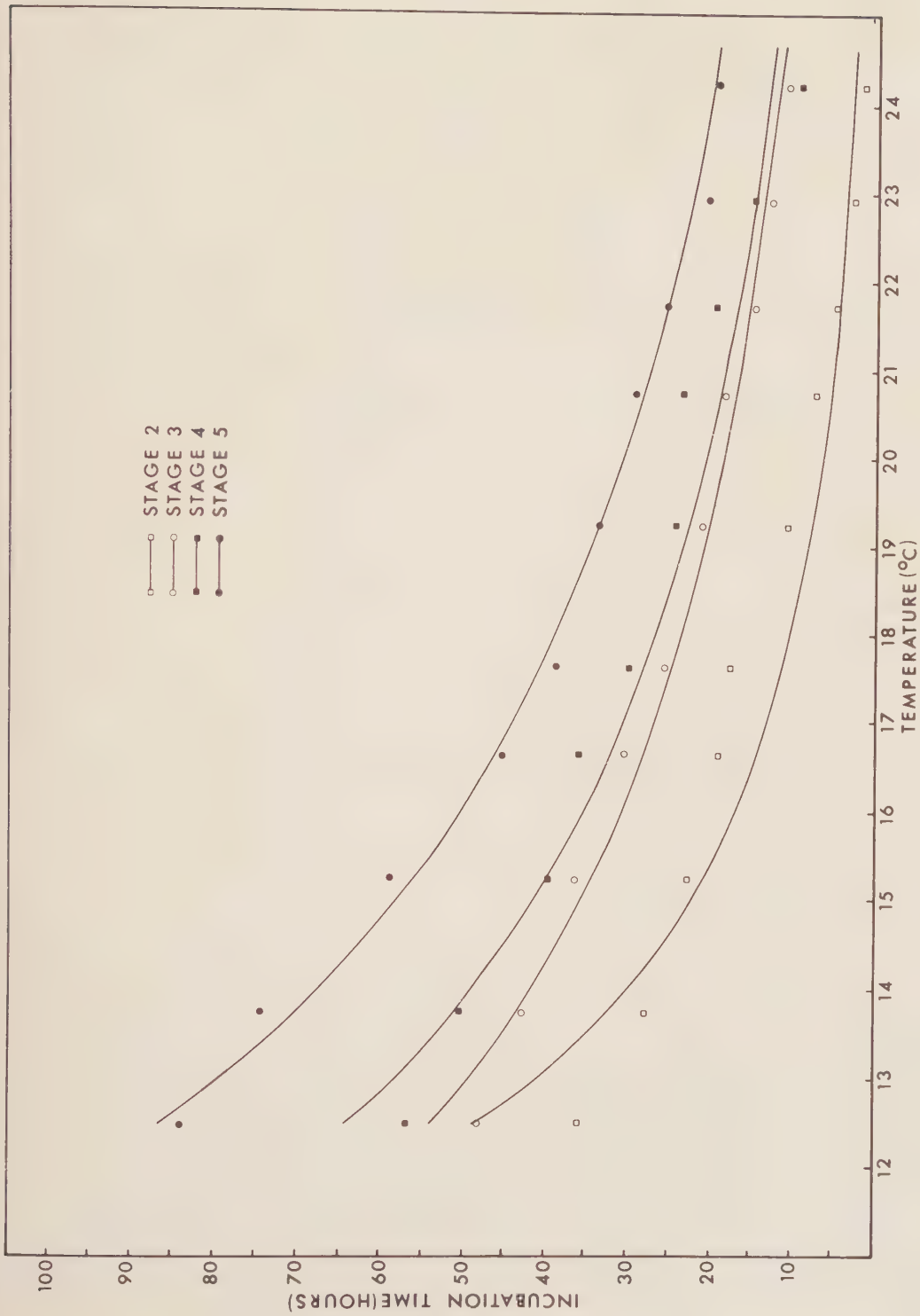

Fig. 3: Incubation time to various stages of egg development in relation to temperature

length of the yolk sac between 0,95 mm and 1,09 mm. In general, pigmentation on the yolk-sac larva shows little difference from that of the late embryonic form. Pigmentation consists of irregularly spaced melanophores along the dorsal and ventral margins of the body (Fig. 4), the dorsal line extending posteriorly from the head to about $\frac{4}{5}$ of the body length. The head region is lightly pigmented in the form of an arch behind the eyes. On the ventral margin, scattered melanophores extend from the posterior end of the yolk sac as far posteriorly as the limit of dorsal pigmentation. A few isolated pigment spots are present on the anterior part of the fin fold. The oil globule is characteristically situated at the anterior part of the yolk sac beneath the head, this position of the oil globule being a useful feature in the identification of *Trachurus* larvae (Ahlstrom and Ball 1954). Newly hatched larvae lack eye pigmentation and the mouth is not yet fully formed.

When the larvae are between 2,50 mm and 3,20 mm in length, the eyes begin to develop pigment and the pectoral fin buds appear. The melanophores on the head region now form a discrete cap and extend forward between the eyes. Pigmentation on the rest of the body remains essentially unchanged except for the disappearance of the small melanophores on the fin fold. The yolk sac is much reduced, the oil globule minute and the mouth rudiments are partially formed.

By the time the larva reaches between 3,0 mm and 4,0 mm, the yolk sac is fully absorbed, the jaws are functional and the eyes are almost completely pigmented. A few scattered melanophores appear on the upper and lower jaws and in the region of the cleithrum.

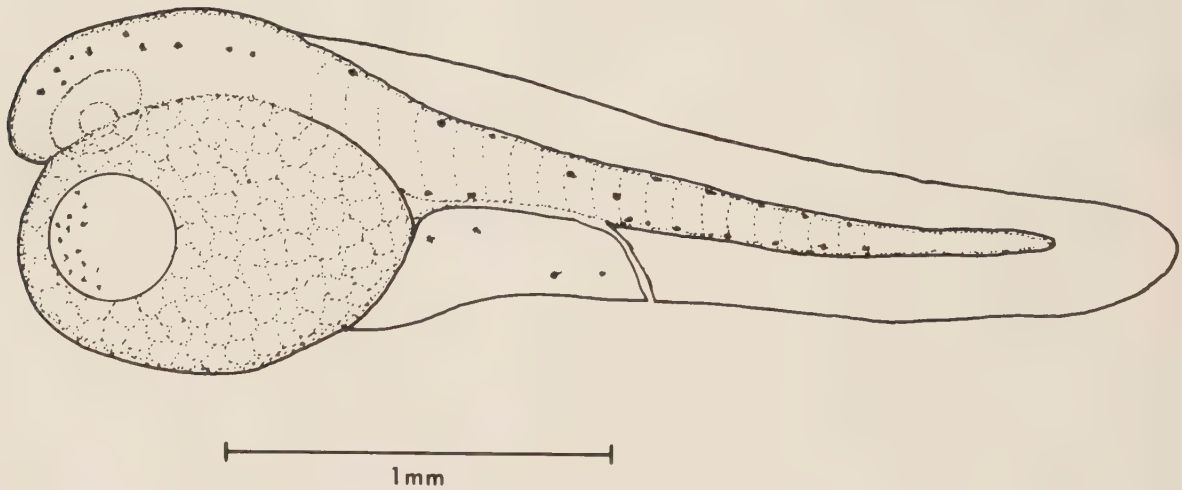

Fig. 4: Newly hatched maasbanker larva measuring 2,60 mm

Growth of the larva

The measurements of newly hatched larvae at 10 incubation temperatures are given in Table III. It is interesting to note that larvae hatched from eggs incubated at lower temperatures were larger than those hatched at higher temperatures.

The growth rate of maasbanker larvae showed a linear correlation with temperature up to the time of yolk absorption (Fig. 5). Owing to excessive mortalities at some temperatures, a mean growth rate was only calculated for the larvae at those experimental temperatures where a significant number had been deemed to survive. The experiments were terminated after yolk exhaustion (3–4 mm long) as heavy mortalities associated with a decrease in size occurred, probably from starvation.

The time of development from hatching to absorption of the yolk in the larva ranged from $5\frac{1}{2}$ days at 12,6°C to 1 day at 24,3°C. Maximum growth rate of larvae was observed at the highest temperature.

Table III: Measurements of newly hatched larvae at 10 incubation temperatures

Temperature (°C)	Number of larvae	Larval length (mm)		Yolk length (mm)	
		Mean	Range	Mean	Range
12,6	6	3,03	3,00–3,10	1,00	0,98–1,00
13,8	5	2,92	2,77–3,05	1,00	0,95–1,00
15,2	5	2,80	2,56–3,00	1,00	0,96–1,09
16,6	6	2,78	2,47–3,10	0,97	0,96–1,00
17,6	4	2,70	2,55–2,89	0,98	0,95–1,00
19,2	5	2,59	2,52–2,85	0,97	0,96–0,98
20,7	5	2,51	2,47–2,50	0,97	0,95–0,99
21,7	4	2,65	2,42–2,75	0,97	0,95–0,98
22,9	4	2,50	2,46–2,57	0,97	0,95–1,00
24,3	5	2,57	2,40–2,84	0,98	0,96–1,00

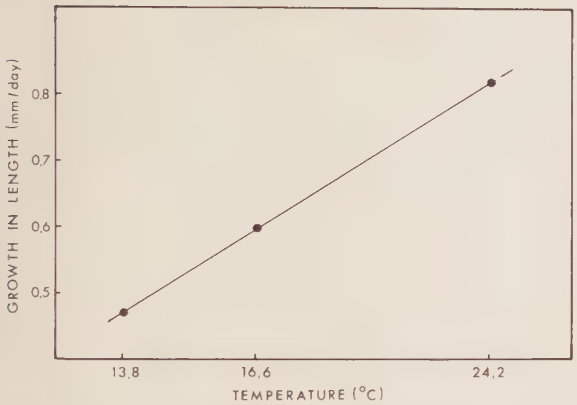

Fig. 5: Growth rate of maasbanker larvae at three incubation temperatures

DISCUSSION

The eggs of the South African maasbanker are similar in appearance but slightly smaller (0,85–0,95 mm) than those of its counterpart in the Northern Hemisphere. The diameter of the oil globule, 0,22 mm (range 0,20–0,27 mm) also compared favourably with the diameters observed by other authors. Heincke and Ehrenbaum (1900) reported that eggs of the North Sea horse mackerel *T. trachurus* had a diameter of 0,81 mm to 1,04 mm and an oil globule diameter of 0,19 mm to 0,28 mm. The size range of the egg of *T. trachurus* from north-west Africa was given as 0,90 mm to 1,10 mm with an oil globule of 0,15 mm to 0,20 mm diameter (Kiliachenkova 1970). Maasbanker eggs identified by Haigh (1972) from Cape waters were found to be seldom larger than 1,00 mm and usually about 0,90 mm with an oil globule of 0,20 mm diameter. Pigmentation on the yolk-sac larvae of all forms is apparently identical.

Until the present study, incubation rates for this species were unknown. However, Ahlstrom (1956) found that the eggs of a related species *Trachurus symmetricus* required about 96 hours to complete development at a temperature of 14,3°C. In contrast, maasbanker eggs hatched after 70 hours at the same temperature. The large difference in incubation times for the two species could be explained if the eggs of *T. symmetricus* had been initially incubated at an earlier stage than those used in this study. Alternatively, real differences in physiological response to temperature may be responsible for the difference in development rate.

It is interesting to compare the incubation times of maasbanker eggs with those of other members of the multispecies pelagic fishery, such as the pilchard *Sardinops ocellata* and round herring *Etrumeus teres*, all of which have planktonic eggs. The development of maasbanker eggs from the blastocap stage to hatching took longer than that of the pilchard. Whereas pilchard eggs required only 66 hours at 13°C and 23 hours at 22°C to develop (King 1975), maasbanker eggs took 80 hours at 13°C and 27 hours at 22°C (calculated from regression formulae) to complete development. Ahlstrom (1956) also reported that the eggs of the jack mackerel *Trachurus symmetricus* required a longer period to develop than the eggs of the Pacific sardine *Sardinops caerulea*. However, the incubation times of round herring eggs are apparently greater than those of the maasbanker. The complete development of round herring eggs requires 95 hours at 13,0°C and 36 hours at 20,5°C (O'Toole and King 1974).

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1977

DISTRIBUTION AND RELATIVE ABUNDANCE OF EGGS OF THE SOUTH WEST AFRICAN PILCHARD *SARDINOPS OCELLATA* AND ANCHOVY *ENGRAULIS CAPENSIS*, 1971/72

D. P. F. KING

As a result of fluctuations in catches of the South West African pilchard, *Sardinops ocellata* Pappe, an intensive research programme was commenced (Cram and Visser 1972). This Cape Cross Programme was designed as a combined biological and ecological investigation into the South West African pelagic resource. As part of this research a preliminary egg survey was conducted from September 1971 until April 1972.

Previously, practically all information about pilchard egg distribution in South West African waters was based on data collected on the routine station network described by Matthews (1964). He described the annual geographic variation in pilchard spawning intensity in the area between Cape Cross (21°50′S) and Conception Bay (24°00′S), this being the main fishing ground then under exploitation (area B in Figure 1). A report on pilchard spawning in relation to temperature for the same area was published by Stander (1963). The present survey carries the earlier investigations a step further and describes the seasonal geographic variations in spawning intensity together with their ecological implications over a much wider area. The abundance of pilchard eggs is also compared with that of previous years.

In addition, the survey was further expanded to include the anchovy *Engraulis capensis* Gilchrist, as little information was available about the spawning behaviour of this species.

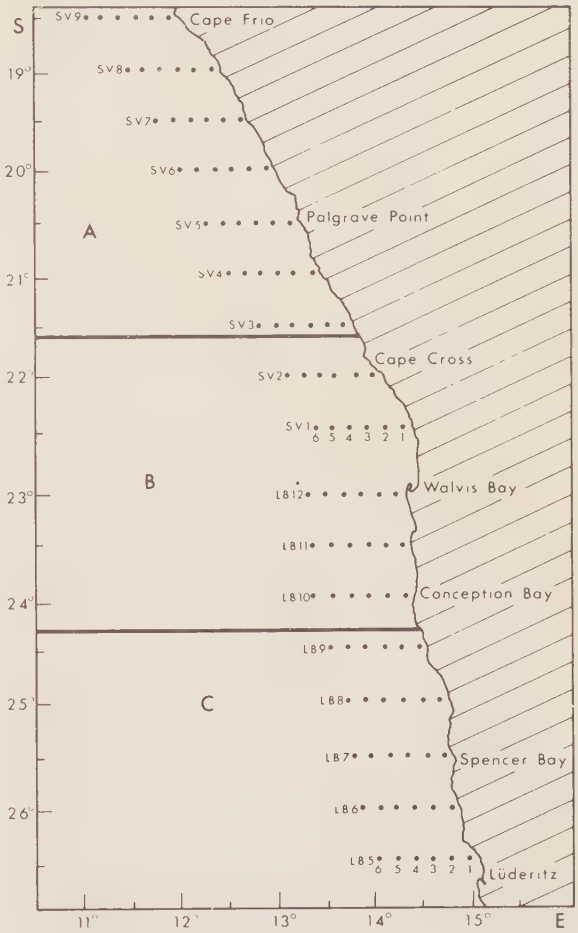

Fig. 1: Distribution of sampling stations and division of the South West African coastal waters into comparative areas

SURVEY AREA AND DESIGN

Matthews (1964) in his 1959–1960 survey, collected large numbers of pilchard eggs in the waters off Cape Cross, the northern limit of his sampling area, but was uncertain whether this was localized spawning or the southern tip of a northern spawning area. Also, plankton data collected on long-line cruises during 1959, 1960 and 1961 indicated that pilchard spawning occurred as far north as Rocky Point (19°00′S). It was therefore evident that the old routine station network off Walvis Bay (Matthews *op. cit.*) did not adequately delimit the geographic extent of pilchard spawning in South West African waters. Consequently, the 1971/72 spawning survey was extended, giving as broad a coverage as possible with the available manpower and resources.

The survey lines were established at intervals of 30 nautical miles, running in an east/west direction. The northern limit was Cape Frio (18°20′S), and the southern limit Lüderitz Bay (27°30′S). This gave a total of 17 lines, each line having 6 stations (Fig. 1).

The first station of each line was 5 miles off shore and the five subsequent stations were spaced at 10-mile intervals. The lines terminated 55 miles off shore. Whenever eggs occurred on the last station of any line, another station was established a further 10 miles off shore. This procedure was continued until no eggs were found.

All lines north of Walvis Bay were designated the prefix SV and consecutively numbered from south to north (SV 1, SV 2 etc.). All lines south of Walvis Bay were designated the prefix LB and consecutively numbered from south to north starting from LB 5. This grid numbering allowed for possible expansion without losing continuity of nomenclature. Although monthly coverage of the 102 stations was planned, a combination of bad weather and loss of gear resulted in curtailment of some cruises (Table I).

Because of the extensive nature of the grid, two research vessels participated in the programme, R.V. *Namib II* sampling the SV lines and R.V. *Crustacea* covering the LB lines.

Table I: Average numbers of pilchard eggs (N100H-net) per station and per positive station during the months of survey (September 1971 to April 1972)

Month	Total number of eggs	Number of positive stations	Average per positive station	Number of stations	Average per station	Percentage positive stations
September	570	5	114	102	6	5
October	64 931	16	4 058	60	1 082	27
November	429	14	31	101	4	14
December	93 800	15	6 253	102	920	15
January	3 257	11	296	63	52	17
February	87 939	26	3 382	82	1 072	32
March	23 605	26	908	101	234	26
April	291	5	58	99	3	5
Total	274 822	118	2 329	710	387	17

SAMPLING GEAR

Two nets, differing in size and in coarseness of mesh were employed to collect the ichthyoplankton samples while the surface temperature was being taken simultaneously.

An N100H-net (Discovery type) was used to collect pilchard eggs and larvae. The net had a 1-metre mouth diameter, was conical in shape and was constructed of 940-µm monofilament nylon netting.

Owing to high phytoplankton concentrations in South West African waters, the conventional N100H/70 mesh net (used for anchovy egg collection in Cape waters) was not suitable. Therefore, a new net, the EES-52 (Experimental Egg Sampler – 52 meshes per inch) was designed to filter less water at a higher sustained rate of efficiency (King and Robertson 1973). This net had a mouth diameter of 50 cm, was cylindro-conical in shape and was constructed of monofilament nylon with an aperture size of 330 µm.

Both nets were towed at each station. The N100H was hauled for 10 minutes and the EES-52 for 5 minutes, at a speed of approximately 2 knots.

RESULTS

Pilchard spawning

To simplify comparisons with results published by Matthews (1964) the survey area was divided latitudinally into three sub-areas: northern (A), central (B) and southern (C) as seen in Figure 1.

The average number of eggs in 1971/72 are summarized by month, station and positive station in Table I. In order to obtain an approximation of the spawning intensity, the number of eggs collected in a particular month was expressed as the number of eggs per positive station.

Spawning occurred continuously from Sep-

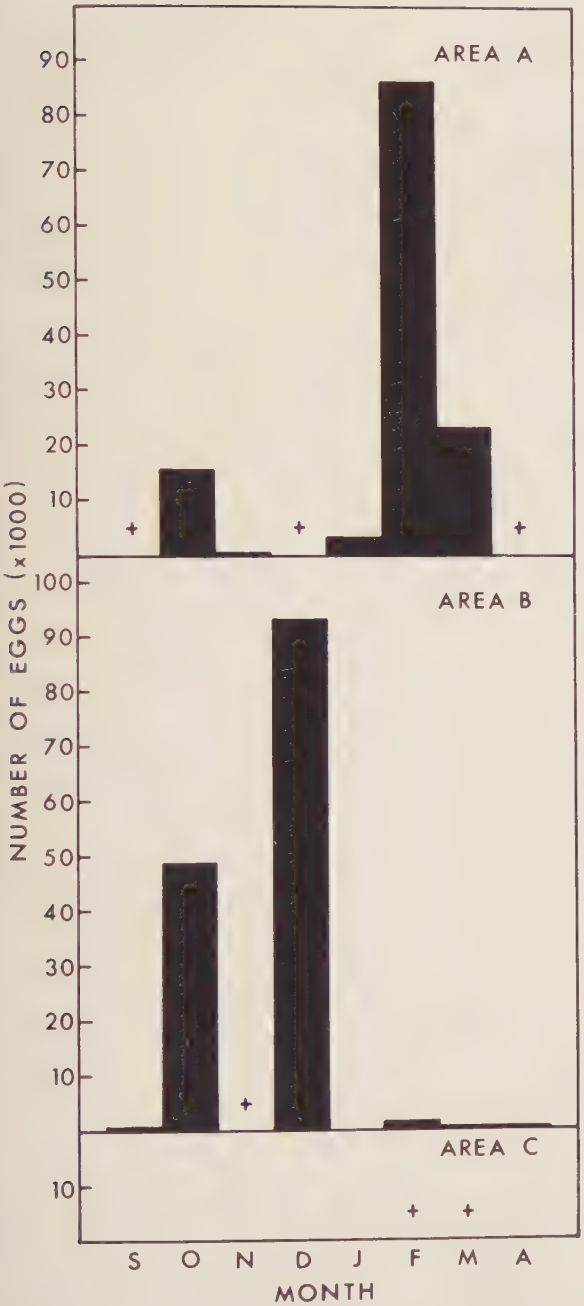

Fig. 2: Distribution of pilchard spawning by area, 1971/72 (+ indicates fewer than 250 eggs)

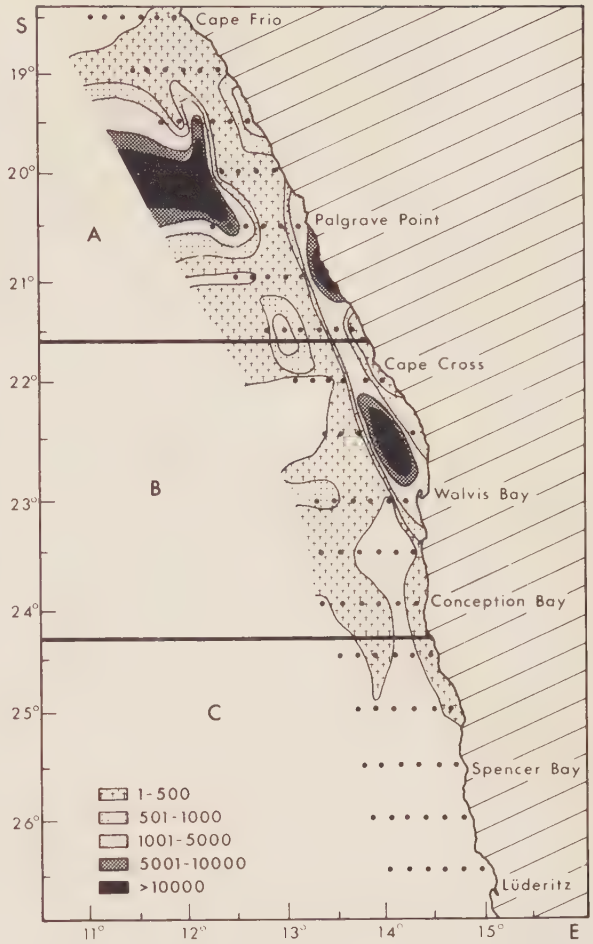

Fig. 3: Distribution and relative abundance of pilchard eggs, September 1971 to April 1972 (cumulative totals)

tember to April. Two spawning peaks can be distinguished from the seasonal histograms shown in Figure 2, one occurring in spring/summer (i.e. September through December) and a second taking place in summer/autumn (i.e. January through April). Two major spawning centres corresponding to these peaks were indicated (Fig. 3). The southern, spring/summer spawning took place over a long expanse of coastline but did not extend far off shore. Peak spawning, as during the 1959 and 1960 seasons was found to lie within 25 miles of the coast between Walvis Bay (line LB 12) and Palgrave Point (line SV 5). Pilchard spawning during the summer/autumn period occurred in the north (lines SV 5 – SV 9) in area A (Fig. 3). The region of peak spawning was centred more off shore than during the

spring/summer period and the westward extent of the spawning area was not discovered.

An appraisal of the relative degree of spawning in the two primary centres during the two seasons was attempted, even though the available information was in no way quantitative. The southern inshore centre consisted of all stations of lines LB 12 – SV 5 from the coastline to seaward of station 3; the northern off-shore centre consisted of all stations occupied to the seaward of station 3 on lines SV 5 – SV 9 in area A. Approximately 95 per cent of all pilchard eggs collected during the survey period were taken in these two areas. The number of eggs collected during spring/summer in the south was 158 043, constituting 57 per cent of the total eggs captured during the survey. The total number of eggs collected during summer/autumn in the northern area was 101 417 or 37 per cent of the total number of eggs obtained during the survey.

One of the more striking results of the 1971/72 survey was the correlation between spawning occurrence and sea surface temperature. The correlation between number of eggs per positive station and temperature is illustrated in Figure 4.

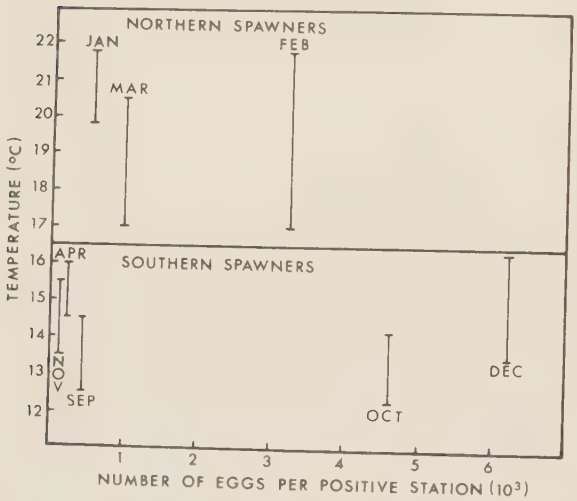

Fig. 4: The average yield of pilchard eggs per positive station in relation to surface temperature

Of special interest is the dividing line which can be drawn between the northern and southern spawning groups at 16,5°C. This means that no summer/autumn off-shore spawning occurred in water with a surface temperature of less than 16,5°C and virtually no spring/summer inshore spawning occurred in water warmer than 16,5°C. This ecological separation has great significance and will be discussed later.

During the 1971/72 spawning cycle the start of spring/summer spawning was later than during previous years and occurred in October rather than August/September. It is suggested that this may have been caused by the intrusions of warm oceanic water into the area, which prevented the normal southward migration of the spawning fish (Schülein 1972).

Figure 3 illustrates the separation of the southern and northern egg collections into separate entities. The high spawning intensity of the spring/summer months was followed by a lull in spawning activity during January. The northern spawning took place in off-shore waters during the summer/autumn period.

This northern, summer/autumn spawning could be the result of either a northward off-shore summer spawning migration or that of a separate spawning group. It is possible that part of the pilchard spawning stock spawns inshore in cold water during spring/summer; spawning then continues off shore as the remainder of the spawning stock move north, until finally the eggs are re-encountered in the northern sampling area. This is a comparable situation with that found in the Western Cape waters (A. S. Anders, Sea Fisheries Branch, personal communication).

The possibility that a separate spawning group exists in the north is supported by:

(i) evidence of fish with active gonads, plus large catches of juvenile pilchard in area A during the spring/summer period; and
(ii) the occurrence of two spawnings in completely different temperature ranges.

This markedly different temperature preference of the summer/autumn spawners has been shown previously (Stander 1963). When this factor is coupled with the geographical distribution of the summer/autumn spawners, the intensity of their spawning and with the information from the fish catches in the area, the hypothesis of a separate spawning group existing in the north has strong evidence for its support.

However, at present there is no categorical proof whether the northern spawning was the result of a northward off-shore spawning migration during the summer months or the result of a separate spawning group in the north. Because of the intensity of the northern spawning, the indications are that the summer/autumn peak is not a secondary one resulting from the pilchard being a serial spawner. Further research is re-

quired to solve this question.

Although the available data was rather inadequate and the factors affecting comparability numerous, an attempt was made to compare 1971/72 results with those of Matthews (1964). Instead of numbers, isopleths were considered, as they gave the most graphic picture of the distribution and abundance of eggs.

The area of highest spawning intensity in 1971/72 was the coastal area between Walvis Bay and Palgrave Point (areas A and B). Matthews (*op. cit.*) in his survey in 1959 and 1960 only covered the area from Cape Cross to Conception Bay (area B) and this area corresponds with the most southern peak of the spring/summer spawning shown in Figure 3. This area in 1971/72 accounted for 90 per cent of the total eggs caught during spring/summer and thus a comparison of the 1959, 1960 and 1971/72 results is of interest. It is apparent that in 1971/72 the distribution was not as wide and the relative abundance not as great as in previous years (Fig. 5). If the spawning in area B is considered representative of the whole spawning area, then the indications are that the spawning in 1971/72 was not as intensive as during 1959 and 1960. Undoubtedly, the lower egg abundance and the geographically more restricted spawning of 1971/72 reflected the lower number of adult fish in South West African waters in comparison with previous years.

Anchovy spawning

As nothing was previously known about anchovy spawning behaviour off South West Africa, the collections made during the programme were useful in assessing the distribution and relative abundance of the eggs of this species.

The seasonal occurrence of anchovy eggs was somewhat different from that of the pilchard, with spawning occurring during the period October to April. However, anchovy eggs did not occur in large numbers until December. February appears as the peak month of spawning, but eggs were also abundant during December-January through March (Fig. 6).

The distribution of anchovy eggs for 1971/72 is shown in Figure 7. As with the pilchard isopleths, the value for each station was the cumulative haul total for the months of survey. The average numbers of anchovy eggs in 1971/72 were summarized by month, station and positive station in Table II.

Anchovy eggs were widely distributed in 1971/72 and occurred at 19 per cent of the stations occupied. Spawning was most intense in area B of the survey area during the spring/summer spawning. However, during the summer/autumn period, the main concentrations of anchovy eggs were found in the south.

During 1971/72, anchovy eggs were taken at temperatures from 13,2°C to 21,8°C, a range of 8,6 deg C (Fig. 8). The frequency of occurrence of anchovy eggs at different temperatures is given in Table III. Approximately 33 per cent of the anchovy eggs were taken within the temperature range 19,0 – 20,5°C, and 68 per cent within a 4,5 deg C range (16,0 – 20,5°C). No anchovy eggs were collected at temperatures below 13,2°C and thus this temperature may be considered the threshold for anchovy spawning. As only a negligible degree of spawning activity was found in waters of surface temperature greater than 21°C, this temperature should thus be taken as the upper limit for anchovy spawning.

Table II: Average numbers of anchovy eggs (EES-52 net) per station and per positive station during the months of survey (September 1971 to April 1972)

Month	Total number of eggs	Number of positive stations	Average per positive station	Number of stations	Average per station	Percentage positive stations
September	—	—	—	102	—	—
October	188	4	47	61	3	7
November	17	6	3	102	0	6
December	24 134	29	832	102	237	28
January	6 675	23	290	72	93	32
February	44 688	34	1 314	100	447	34
March	14 831	39	380	98	151	40
April	881	10	88	99	9	10
Total	91 414	145	630	736	124	19

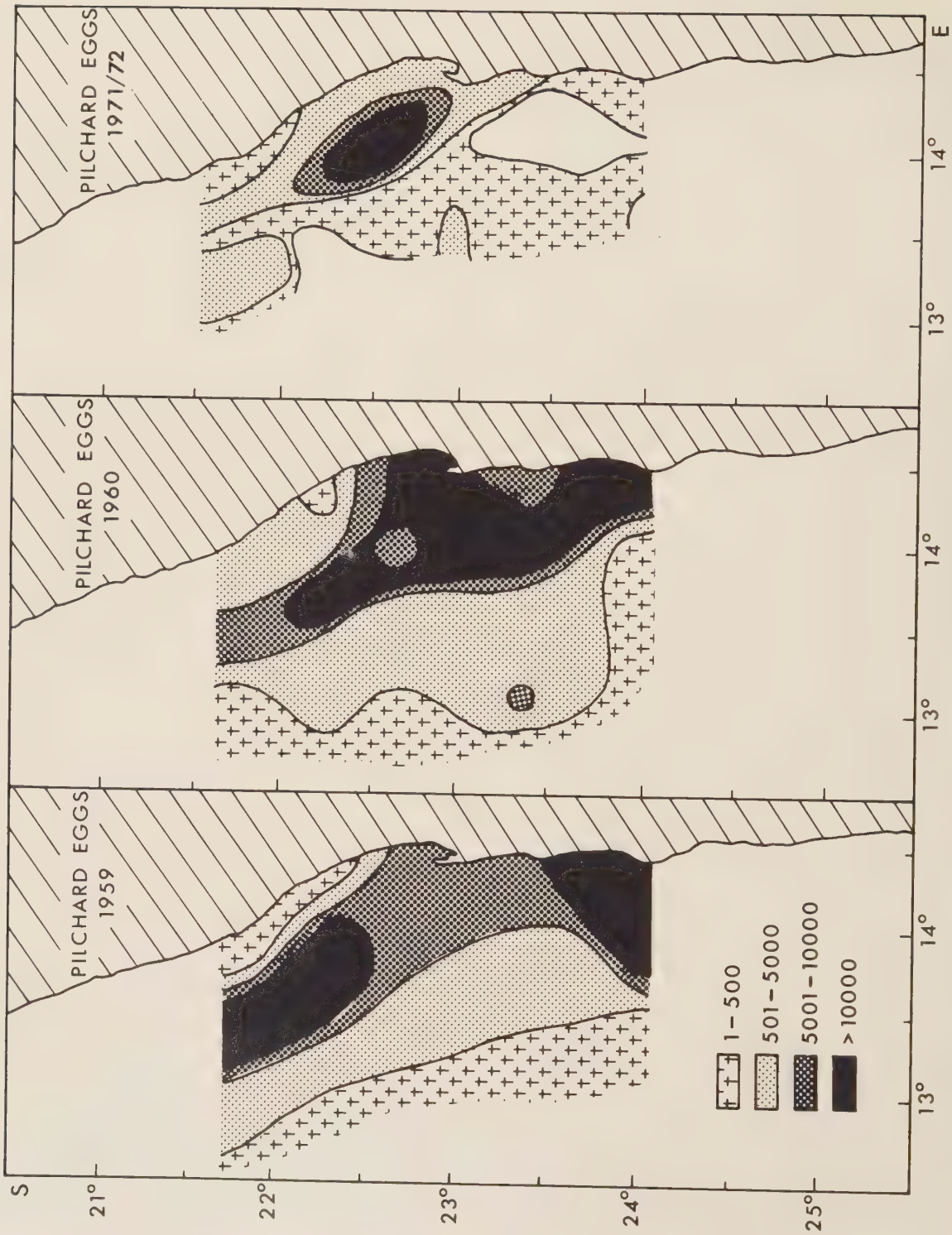

Fig. 5: The distribution and relative abundance of pilchard eggs in 1959 and 1960 (after Matthews 1964) and 1971/72 — cumulative totals

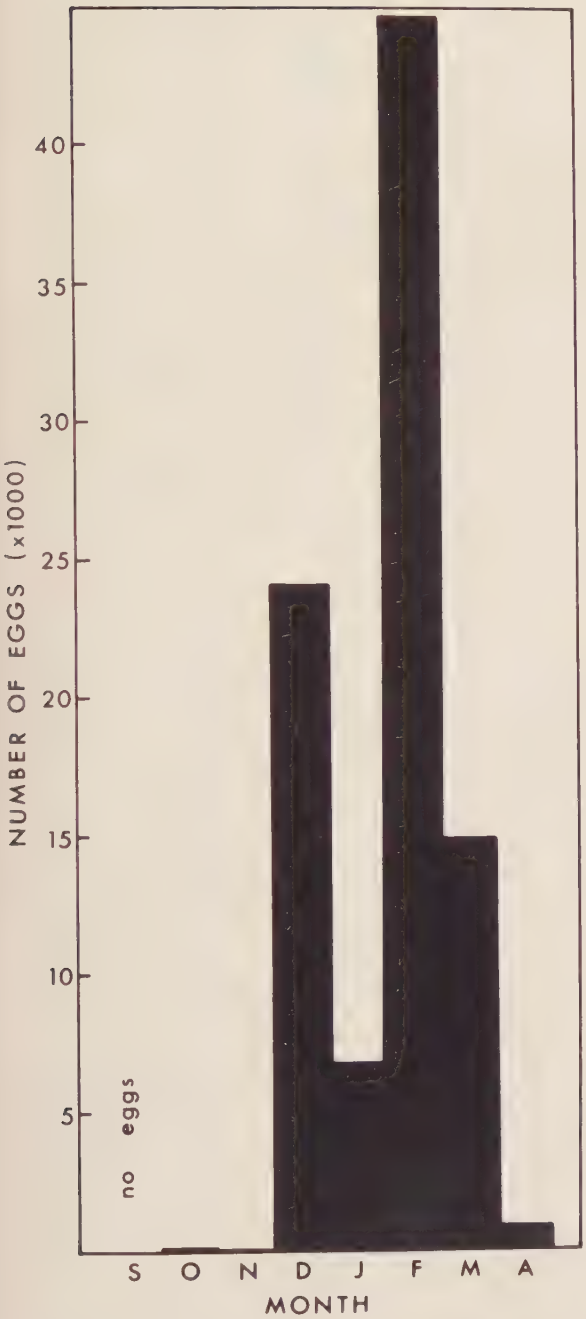

Fig. 6: Number of anchovy eggs collected per month (EES-52 net), September 1971 to April 1972

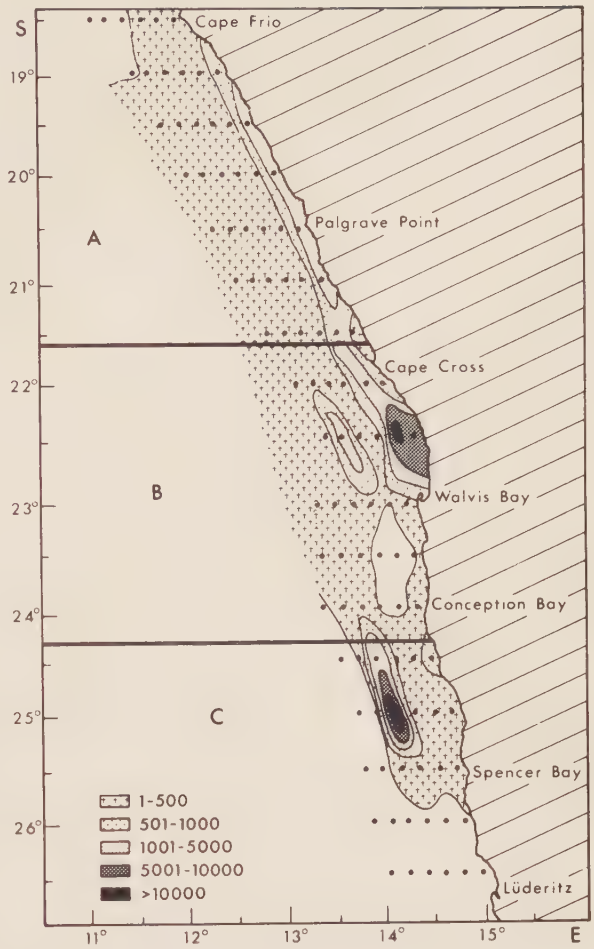

Fig. 7: Distribution and relative abundance of anchovy eggs, September 1971 to April 1972 (cumulative totals)

Comparison of anchovy and pilchard spawning

Table IV lists the abundance of anchovy and pilchard eggs during 1971/72. Only counts from the EES-52 net were compared as the pore size of N100H net material was too coarse for retention of anchovy eggs. Anchovy eggs outnumbered pilchard eggs in the survey area in a ratio of 1,46 : 1.

The area over which anchovy spawned in 1971/72 was more restricted than that of the pilchard since the anchovy eggs were found mainly in the coastal belt. For both species, the most intense spawning occurred in area B during spring/summer, but in summer/autumn, most pilchard

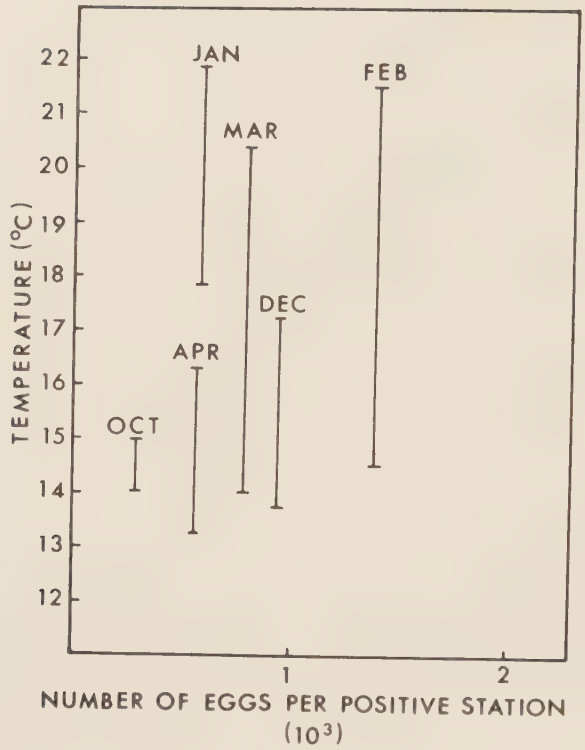

Fig. 8: The average yield of anchovy eggs per positive station in relation to surface temperature

Table III: Relationship between the occurrence of anchovy eggs and surface temperature, 1971/72

Surface temperatures (°C)	Occurrences of anchovy eggs
13,0–13,4	2
13,5–13,9	1
14,0–14,4	4
14,5–14,9	8
15,0–15,4	7
15,5–15,9	3
16,0–16,4	7
16,5–16,9	5
17,0–17,4	5
17,5–17,9	4
18,0–18,4	7
18,5–18,9	5
19,0–19,4	8
19,5–19,9	8
20,0–20,4	16
20,5–20,9	4
21,0 21,4	1
21,5–21,9	1

Table IV: Monthly totals of pelagic egg counts taken with EES-52 net during the period September 1971–April 1972

Month	Pilchard eggs	Anchovy eggs	Other fish eggs
September	192	—	11 709
October	6 488	188	4 430
November	109	17	684
December	26 186	24 134	1 229
January	856	6 675	269
February	19 051	44 688	6 763
March	9 726	14 831	4 973
April	12	881	62 700
Total	62 620	91 414	92 757
Percentage of all eggs	25,4	37,0	37,6

spawning took place off shore in the north while that of anchovy was concentrated in the south.

Larvae

Although these studies centred mainly on the eggs of the pilchard and the anchovy, it was hoped that the collections would be useful in assessing the distribution of the larval stages. However, little success was had owing to the inefficiency of the gear for sampling larvae. The results are presented in Table V.

Most of the pilchard larvae caught were between 4,0 mm and 6,0 mm standard length and the highest numbers were found in area A during April. This was the main spawning ground of the summer/autumn spawners Only 51 anchovy larvae were captured during the survey. The poor catch-rate of larvae probably resulted from a combination of the following factors:

(i) many larvae are found deeper than the sampling depth of the nets,
(ii) the mesh sizes of the nets were too coarse to retain the smaller larvae,
(iii) the larger larvae are more active and thus more able to take avoidance action.

FUTURE RESEARCH

The egg programme was restricted in its aims because of unsuitability of equipment and limited capabilities of the available research vessels. However, despite these inadequacies, the results

Table V: Occurrences and abundance of pilchard and anchovy larvae by station and month, 1971/72

Month	Station number	Temperature (°C)	Net type	Pilchard			Achovy		
				Number	Mean standard length (mm)	Range	Number	Mean standard length (mm)	Range
October	SV 3–4	14,0	N100H	1	4,02		—		
	LB 11–5	13,0	EES–52	2	4,44	4,38–4,50	—		
November	SV 2–4	14,8	EES–52	1	3,55		—		
	SV 6–1	13,9	EES–52	8	3,90	3,50–4,10	—		
	SV 6–1	13,9	N100H	16	4,96	4,50–5,70	—		
December	SV 9–4	15,8	N100H	—			36	3.40	3,30–3,90
	SV 9–6	17,4	N100H	—			1	3,30	
January	SV 3–2	20,6	N100H	1	5,35		—		
	SV 4–2	20,0	N100H	2	5,40	5,40	—		
February	SV 5–5	20,1	N100H	2	6,00	5,82–6,18	—		
	SV 6–3	20,4	N100H	1	5,03		—		
	SV 7–3	21,4	N100H	1	4,06		—		
	SV 7–4	21,3	N100H	29	5,40	5,20–5,90	1	10,00	
	SV 7–6	20,3	EES–52	—			1	12,00	
	SV 8–4	20,1	N100H	56	8,40	7,71–18,36	2	15,00	12,00–18,00
	SV 8–4	20,1	EES–52	10	7,40	7,30–18,12	—		
March	SV 7–6	20,5	EES–52	—			2	5,80	5,65–5,95
April	SV 5–6	18,2	N100H	19	4,05	4,00–4,90	3	5,50	5,20–5,90
	SV 8–3	17,9	N100H	241	7,96	7,74–8,96	5	14,80	10,00–19,00
	SV 8–3	17,9	EES–52	59	5,82	5,60–6,80	—		
	SV 8–4	18,8	EES–52	2	18,00	16,00–20,00	—		

of the programme were of considerable value in planning a more complex survey of the pilchard spawning centres. This culminated in the initiation of the South West African Pelagic Egg and Larval Survey (SWAPELS) in spring 1972.

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Dr A. H. B. De Decker and Messrs L. Botha, M. J. O'Toole and A. I. L. Payne are thanked for their useful suggestions and constructive criticism of the manuscript.

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1977

DEVELOPMENT AND DISTRIBUTIONAL ECOLOGY OF THE LARVAE OF THE WEST COAST SOLE *AUSTROGLOSSUS MICROLEPIS*

M. J. O'TOOLE

Austroglossus microlepis (Bleeker), commonly known as the West Coast sole, supports a small but important demersal fishery on the Atlantic coast of southern Africa. The commercial fishery for this species is particularly well developed in South West Africa where landings have fluctuated between 150 metric tons in 1960 and 1 895 tons in 1973 (statistics collected by the South West African Administration and the Sea Fisheries Branch).

The West Coast sole is strictly an Atlantic form and can readily be distinguished from other species found in the area by its general body shape, relatively large size, and differences in fin ray counts (Smith 1970). Despite the existence of a commercial fishery, larval development has not been described and information on the ecology of the eggs and the larvae is relatively scarce. Gilchrist and Hunter (1920) have described and illustrated the egg and newly hatched larva, reporting that they were fairly common from August to early September near St Helena Bay off the west coast of South Africa. West Coast sole eggs were recently collected in Hout Bay (34° 03′S) and the larvae reared for a period of 16 days (C. Brownell, University of Cape Town, personal communication).

In August 1972, the Sea Fisheries Branch commenced an extensive egg and larval research programme (SWAPELS) off South West Africa to study the spawning of the pilchard *Sardinops ocellata* Pappe and the anchovy *Engraulis capensis* Gilchrist. Cruises were undertaken from August 1972 to March 1973 and from August 1973 to April 1974. Although eggs of the West Coast sole were possibly present in the collections, they were not identified and thus are not mentioned in this report. During the course of the investigation, larvae of *A. microlepis* were identified and found to be relatively common in the inshore plankton. Results of the first survey showed that larvae of the family Soleidae accounted for three per cent of all fish larvae collected (O'Toole 1973). Larvae of the West Coast sole themselves accounted for 42 per cent of the sole larvae and ranked sixth in order of species abundance. During the second survey, *A. microlepis* constituted only one per cent of all fish larvae captured but was the seventh most abundant species in the plankton.

This report describes and illustrates the larval development from the yolk-sac stage to the juvenile. Information is also given on such aspects as larval seasonality, distribution, abundance and dispersal and the influence of hydrology.

MATERIAL AND METHODS

The research area, together with the location of routine stations, is shown in Figure 1. Ichthyoplankton collections were made in the 0–50 m layer using 57-cm diameter Bongo nets with meshes of 0,940 and 0,500 mm. Further details of the methods, sampling procedure and net performance is given by King and Robertson (1973) and O'Toole (1977). Station positions and depths are listed by O'Toole (1976). The number of larvae captured by the nets at each station was standardized to the total number under 10m² of sea surface (see Kramer *et al.* 1972, Ahlstrom 1973). Larval distribution charts were drawn on the assumption that larval density gradients between stations were linear in space and time. Abundance is expressed as the number per 10 m² of sea surface.

The larvae of *A. microlepis* were first identified by diagnosing the adult characteristics in some juvenile specimens. A developmental series was then built up by tracing these distinguishing meristic data and pigmentation patterns back to the yolk-sac stage. In advanced specimens, meristic counts were made after clearing and staining by the trypsin-alizarin technique of Taylor (1967).

Larvae were examined through a binocular microscope and measured to the nearest hundredth of a millimetre with an ocular micrometer. The length of large specimens was taken against a finely graduated glass slide. All observations were made from the right side. The lengths of yolk-sac and early larval stages were

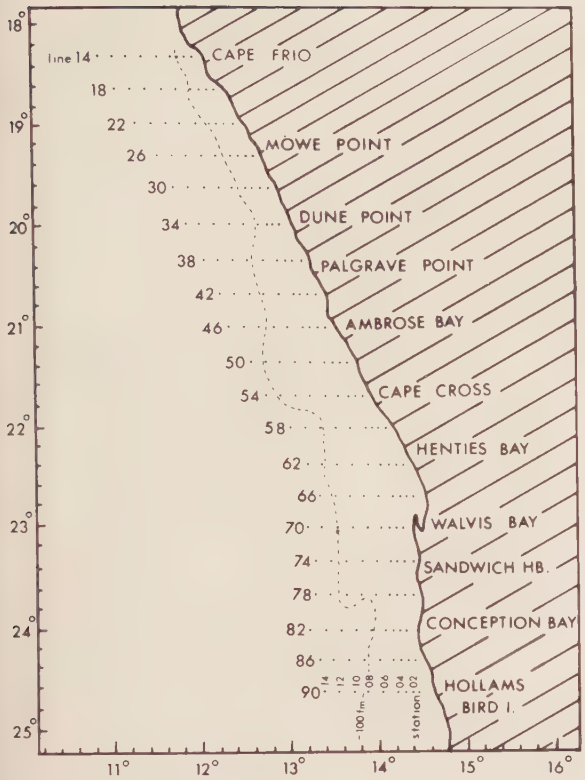

Fig. 1: Location of routine stations occupied during the SWAPELS cruises

measured from the anterior border of the head to the tip of the notochord and, after caudal fin ray formation, from the tip of the snout to the base of the median caudal rays (standard length, SL). Head length was measured from the tip of the snout to the cleithrum and body depth from the anal opening to the base of the dorsal fin.

Since the larvae examined during this study were preserved in 10 per cent buffered formalin, the lengths of the specimens, especially of the early stages, were probably less than those of live fresh material. The yolk-sac larva of the sole, *Heteromycteris capensis* Kaup, was found to shrink as much as 15 per cent when fixed in preservative (C. Brownell, University of Cape Town, personal communication). The shrinkage of larvae was not taken into account when describing the development or establishing the length distribution, but, since the larvae were preserved and measured in the same way throughout the investigation, the length distribution was assumed to be comparable from year to year.

RESULTS

Larval development

A total of 541 specimens ranging in size from 2,85 mm to 23,00 mm SL was collected during the ichthyoplankton surveys. A series of larvae considered to be representative of most developmental stages was selected from the samples for description and is illustrated in Figures 2 and 3. Morphometric measurements and meristic counts were made on 160 specimens in 17 length classes (in order to cover a fuller length range, the collection was supplemented by a few larvae caught in the same area by other methods). The results are given in Table I.

Yolk-sac larva – According to Gilchrist and Hunter (1920) the length range of newly hatched larvae was 1,65–1,98 mm. C. Brownell (University of Cape Town, personal communication) found that the length on hatching was 1,80 mm. The smallest larva collected during this survey had little yolk and was relatively well developed suggesting that the yolk-sac phase was nearing completion. It had a notochord length of 2,85 mm. The eyes were fully pigmented and the mouth was functional (Fig. 2A). Pectoral buds were well developed and the dorsal, ventral and caudal regions of the body were surrounded by a large fin fold. The gut was fully formed and typically S-shaped.

Pigmentation consisted of a series of 8–10 widely spaced melanophores situated along the dorsal and ventral surfaces of the body at the base of the fin fold. A few prominent melanophores were present on the fin fold itself. Small contracted pigment spots were scattered on the yolk-sac, lower jaw, pectoral fin and on the head region behind the eye. Myomeres were not very distinct but at least 45 could be counted. In some specimens, several small oil globules were discernible in the abdominal sac, approximately midway along the ventral surface.

Larva – the larval stage of development in teleosts is often defined as that period between the absorption of the yolk sac and the acquisition of the full complement of adult fin rays. In

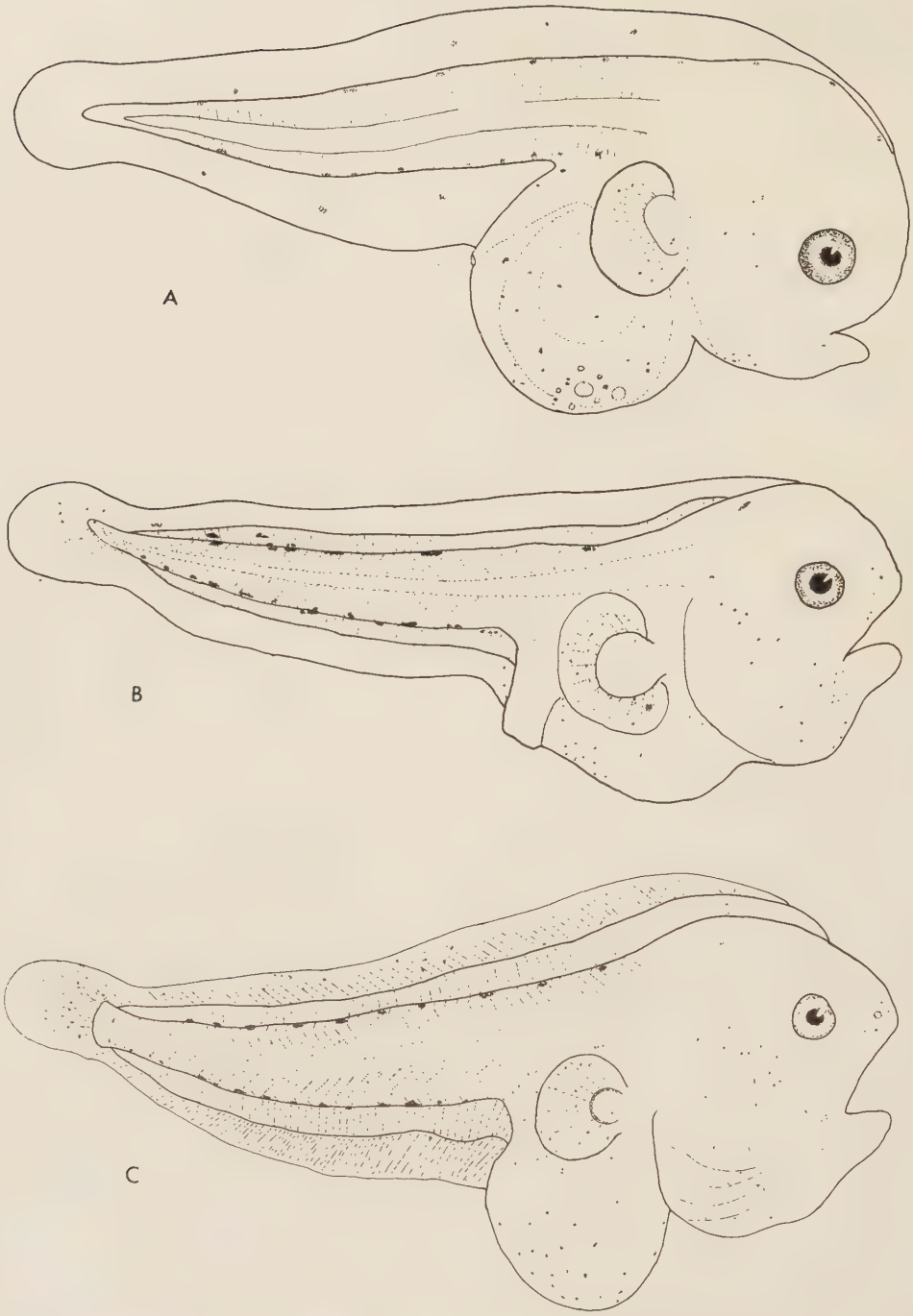

Fig. 2: Early larval development of the West Coast sole *Austroglossus microlepis*.
A: Yolk-sac larva 2,85 mm, B: Larva undergoing flexion 5,50 mm,
C: Larva after flexion 6,60 mm

Fig. 3: Later larval development of the West Coast sole *Austroglossus microlepis*.
A: Larva 9,60 mm, B: Metamorphosing larva 15,50 mm,
C: Fully metamorphosed juvenile 23,40 mm

Table I: Morphometric measurements and meristic counts for larvae of the West Coast sole *Austroglossus microlepis*

Specimen length (mm)		Number of larvae	Mean percentage of specimen length				Fin counts (range)		
Range	Mean		Head length	Body depth	Eye diameter	Pre-anal length	Dorsal	Caudal	Anal
2,85–2,98	2,90	10	28,97	29,66	9,31	53,45			
3,10–3,85	3,60	10	23,61	24,17	7,50	43,89			
4,00–4,87	4,52	20	20,80	27,21	6,64	39,16			
5,32–5,76	5,50	16	27,27	33,82	5,45	41,45			
6,15–6,79	6,45	14	30,70	36,28	5,27	44,96	18–20	10–12	12–13
7,20–7,92	7,57	12	26,02	34,21	4,40	35,01	86–89	18–19	69–74
8,32–8,76	8,55	13	27,37	35,09	4,21	43,24	90–92	18–19	72–73
9,00–9,60	9,30	10	30,00	34,95	4,19	40,32	92–95	18–19	72–73
10,29–10,60	10,43	11	28,19	38,73	4,12	38,06	93–94	18–19	72–73
11,15–11,80	11,48	6	25,17	31,10	3,48	31,10	94–95	18–19	73–74
12,32–12,87	12,56	6	26,43	33,12	3,18	28,82	93–95	19	73–74
13,30–13,85	13,65	8	26,37	32,23	3,00	26,37	93–95	19	73–74
14,21–14,97	14,45	7	25,76	32,18	3,11	25,26	93–95	19	74–75
15,00–15,60	15,47	7	23,85	31,35	2,91	25,53	94–95	19	74–75
16,20–16,89	16,60	8	23,49	29,82	2,71	29,82	92–94	18–19	75
18,60	18,60	1	25,81	27,42	2,55	30,65	95	18–19	75
23,40	23,40	1	24,83	30,13	2,82	26,92	94	19	74

the West Coast sole, this phase occurs between lengths of 3 mm and 8 mm.

During larval development, pigmentation is basically similar to that of the yolk-sac stage. However, the dorsal and ventral melanophores along the body margin increase in number and become somewhat embedded. The large melanophores on the fin fold disappear at a length of approximately 3 mm and the region becomes speckled with small pigment spots. Pigmentation increases gradually on the head and the gut. Tail flexion commences in larvae of between 5,20 mm and 5,50 mm length. A larva undergoing flexion is illustrated in Figure 2B. During this process, the pterygiophores are formed and the dorsal, anal and caudal fin rays commence development. The urostyle is fully flexed and the caudal fin rays are almost complete at a length of 6,60 mm (Fig. 2C). The nares are visible as a single small tubercle on the snout anterior to the eye. The full complement of dorsal and anal fin rays is attained at a length of 7,50 mm, and the fins themselves are lightly speckled with small pigment spots. Myomeres number between 56 and 58.

Metamorphosis – Metamorphosis commences at lengths between 8,25 mm and 8,50 mm when the anterior part of the dorsal fin separates from the head to form the characteristic rostral hook. The left eye begins to migrate slowly to the right side. A larva at an early stage of metamorphosis is shown in Figure 3A.

Juvenile pigmentation appears in specimens of lengths 13,00–13,50 mm. The row of dorsal and ventral melanophores along the body surface begins to intensify and expand. Pigment spots along the base of the dorsal and anal fins aggregate into discrete groups and stellate melanophores form in broad patches along the body mid-line. Pigmentation on the head increases.

The pectoral fins appear to be reduced and the pelvic fin appears as a small bud anterior to the stomach in specimens of 13,20 mm length. At lengths of 15,00–15,50 mm the left eye has migrated over to the right side beneath the rostral hook (Fig. 3B). Metamorphosis into the juvenile form is complete at a length of 24 mm (Fig. 3C). Pigmentation on the body consists of five broad bands of large stellate melanophores running longitudinally across the body from the dorsal to the anal fin rays. Both pectoral fins are noticeable and the general body shape is typically adult.

Distribution and abundance

The geographic distribution and abundance of West Coast sole larvae for both survey periods are shown in Figures 4 and 5. Larvae were collected predominantly from inshore waters between Cape Cross and Hollams Bird Island no further than 16 km from the coast. The percentage occurrence in the different parts of

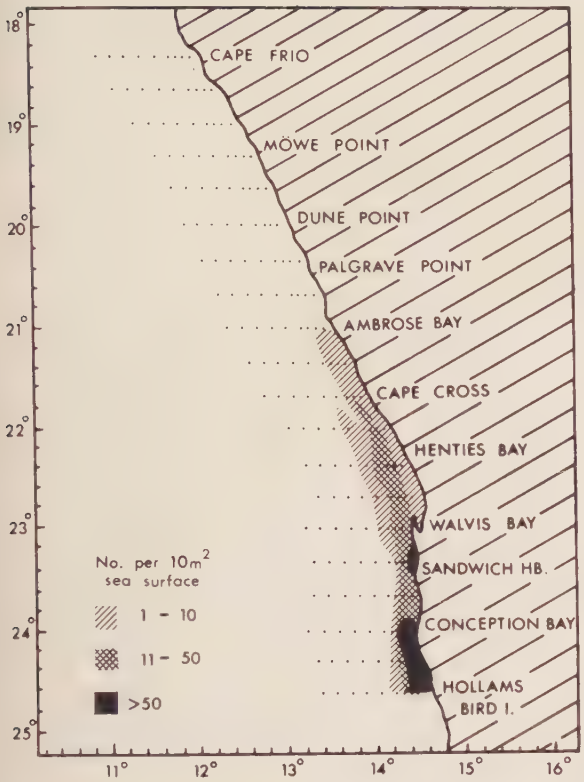

Fig. 4: Survey 1 – Distribution and abundance of West Coast sole larvae (values represent cumulative haul totals for all cruises)

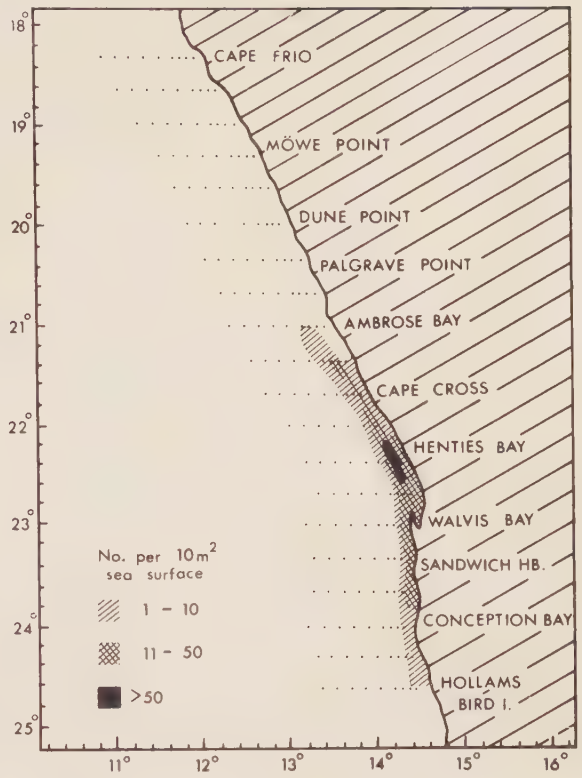

Fig. 5: Survey 2 – Distribution and abundance of West Coast sole larvae (values represent cumulative haul totals for all cruises)

the research area is summarized in Table II.

The northern limit of occurrence was in the region of Palgrave Point, with only a few specimens being caught further than 30 km from the coast.

Larvae of the West Coast sole were collected mainly during spring (September to November). Approximately 95 per cent and 73 per cent of the total number captured during surveys 1 and 2 respectively were collected in these months.

Survey 1 (August 1972–March 1973) – The monthly distribution and abundance of West Coast sole larvae collected during survey 1 are shown in Figure 6. All localities mentioned in subsequent discussion are illustrated in Figure 1. The distribution of surface temperature is also shown and is discussed later. The monthly hauls and larval abundance are summarized in Table III and the size composition of the catches in Table IV.

Table II: Percentage of larvae collected in the different parts of the research area

Area	Station lines	1972/73	1973/74	1972/74
Cape Frio – Möwe Point	14–26			
Möwe Point – Palgrave Point	30–42			
Palgrave Point – Henties Bay	46–58	8,45	38,80	16,75
Henties Bay – Sandwich Harbour	62–74	25,00	42,87	39,22
Sandwich Harbour – Hollams Bird Island	78–90	66,55	18,33	44,13

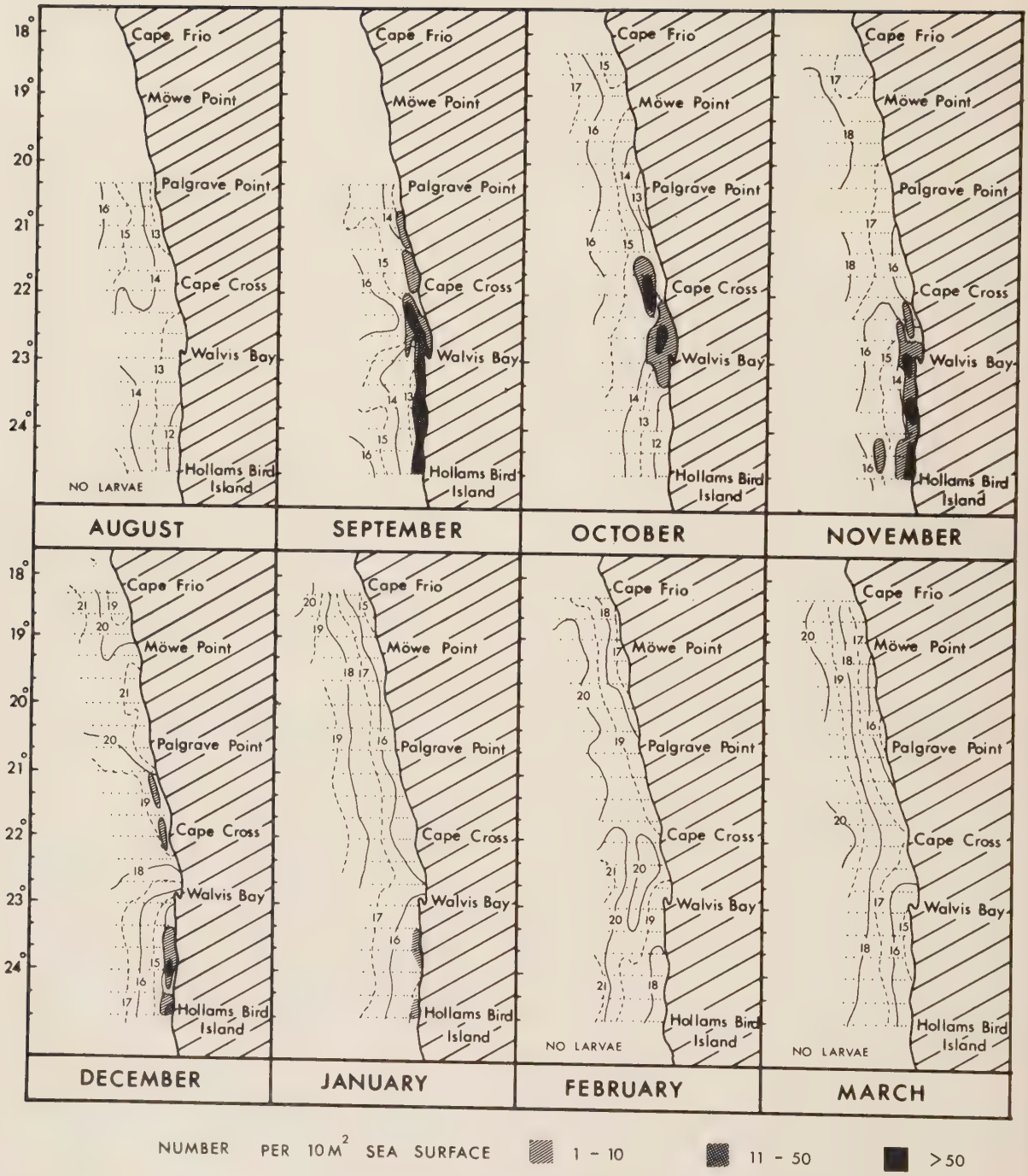

Fig. 6: Survey 1 – Monthly distribution and abundance of West Coast sole larvae related to surface temperature

Table III: Monthly hauls and abundance of West Coast sole larvae, 1972/73

Cruise dates	Number of hauls	Number of positive hauls	Number of larvae collected	Mean number of larvae per 10 m² sea surface	Percentage of total collected
August 22–31	126	0	0		
September 15–20	126	17	195	18,59	54,0
October 15–22	156	8	26	6,81	7,2
November 11–19	180	14	122	15,30	33,8
December 5–14	180	6	14	5,95	3,9
January 13–21	180	3	4	2,92	1,1
February 14–24	177	0	0		
March 11–19	177	0	0		

Larvae first appeared in the plankton during September in the coastal waters between Cape Cross and Hollams Bird Island, the specimens being predominantly recently hatched and ranging in size from 2,85 mm to 13,00 mm. Although age could not be determined, it is very likely that these specimens were 3–14 days old and hatched from eggs spawned between late August and early September. Larvae were particularly abundant off Conception Bay and Hollams Bird Island.

In October, West Coast sole larvae were scarce in the collections and only occurred in the coastal region between Cape Cross and Walvis Bay. These larvae were generally larger than those taken in September and ranged between 5,00 mm and 12,80 mm in length, suggesting that some of the specimens may have represented the same population that had been sampled in September.

Larvae were more widespread and numerous in the plankton during November. The regional distribution was similar to that of September, but peak abundance occurred inshore near Hollams Bird Island. Approximately 85 per cent of the specimens were recently hatched and measured between 2,85 mm and 6,00 mm in length, thus suggesting that renewed spawning took place in the coastal waters south of Walvis Bay in early November.

December was marked by a sharp drop in the number of larvae captured. Isolated specimens, consisting mainly of mixed size classes (4,00–12,00 mm), were found scattered between Sandwich Harbour and Hollams Bird Island.

In January, only four specimens were caught, all south of Walvis Bay, ranging between 5,00 mm and 15,00 mm in length. No West Coast sole larvae were found during February or March.

Table IV: Size composition of West Coast sole larvae in 1972/73

Length group (mm)	September		October		November		December		January		All months	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
2,1–3,0	43	22,1			28	23,0					71	19,7
3,1–4,0	68	34,9			25	20,5					93	25,8
4,1–5,0	46	23,6			16	13,1	1	7,1			63	17,5
5,1–6,0	19	9,7	3	11,1	21	17,2	1	7,1	1	25,0	45	12,5
6,1–7,0	13	6,6	6	22,2	14	11,5	2	14,2			35	9,7
7,1–8,0	4	2,1	2	7,4	5	4,1					11	3,0
8,1–9,0	1	0,5	9	37,0	4	3,3	4	28,6			18	5,0
9,1–10,0			3	11,1	3	2,5	3	21,4			9	2,5
10,1–11,0			2	7,4	2	1,6	2	14,3			6	1,7
11,1–12,0							1	7,1			1	0,3
12,1–13,0	1	0,5	1	3,7	1	0,8					3	0,8
13,1–14,0					2	1,6			2	50,0	4	1,1
14,1–15,0									1	25,0	1	0,3
15,1–16,0					1	0,8					1	0,3

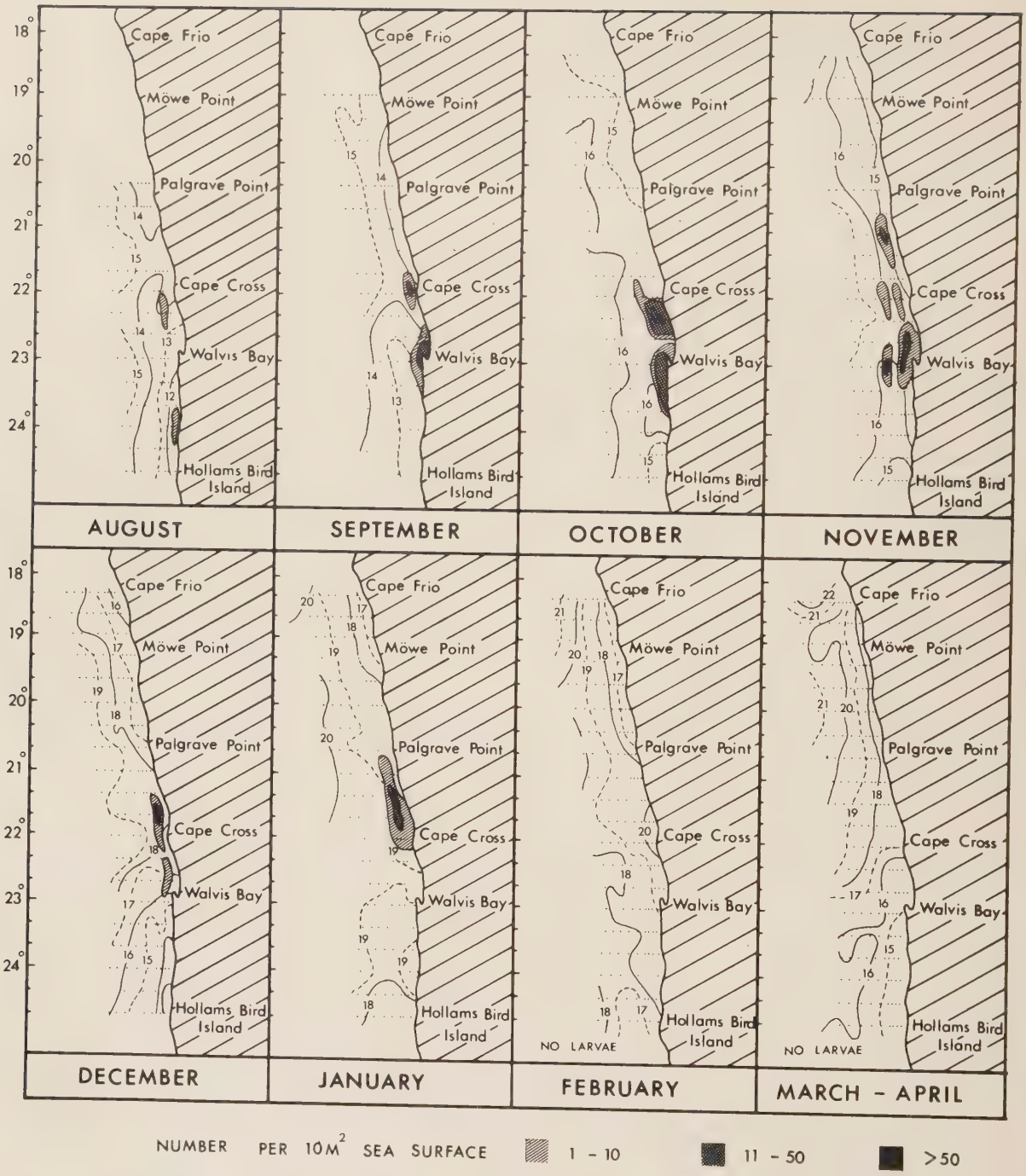

Fig. 7: Survey 2 – Monthly distribution and abundance of West Coast sole larvae related to surface temperature

Table V: Monthly hauls and relative abundance of West Coast sole larvae, 1973/74

Cruise dates	Number of hauls	Number of positive hauls	Number of larvae collected	Mean number of larvae per 10 m² sea surface	Percentage of total collected
August 14–19	126	2	2	2,25	1,1
September 9–15	135	3	14	8,95	7,8
October 17–23	180	21	106	11,00	58,9
November 10–18	180	12	19	4,08	10,5
December 10–18	180	5	21	8,11	11,7
January 12–20	180	7	18	9,98	10,0
February 6–14	169	0	0		
March 27 – April 4	175	0	0		

Survey 2 (August 1973–March/April 1974) – West Coast sole larvae were less abundant in the plankton during survey 2. However, the geographic distribution was similar to that of survey 1. Larvae were found from August to January.

Monthly distribution and abundance of larvae for the 1973/74 survey cruises together with the temperature distribution are illustrated in Figure 7. The relative abundance and the number caught per haul are summarized in Table V and the length composition of the larvae by month in Table VI.

Only two specimens measuring 4,50 mm and 9,35 mm were captured during August. These isolated specimens were found approximately 24 km west of Henties Bay and 10 km west of Conception Bay respectively. In September, larvae were still relatively scarce with only small patches occurring inshore off Walvis Bay and Cape Cross. Specimens measured from 4,35 mm to 14,75 mm and were probably derived predominantly from eggs spawned in late August and early September.

West Coast sole larvae were taken in greatest numbers during the October cruise and were distributed along the coast between Cape Cross and Conception Bay. The greatest concentration of larvae was found about 16 km west of Henties Bay, most specimens being early larval stages, suggesting an increase in spawning activity in early October.

During November, December and January few

Table VI: Size composition of West Coast sole larvae in 1973/74

Length group (mm)	August		September		October		November		December		January		All months	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
2,1–3,0					25	23,6							25	13,8
3,1–4,0					37	34,9							37	20,6
4,1–5,0	1	50,0	3	21,4	12	11,3	1	5,3					17	9,4
5,1–6,0			2	14,3	14	13,2	1	5,3			1	5,6	18	10,0
6,1–7,0			4	28,6	10	9,4	3	15,8	1	4,8			18	10,0
7,1–8,0			1	7,2	4	3,7	6	31,6	2	9,5			13	7,2
8,1–9,0					4	3,7	5	26,2	3	14,3	1	5,6	13	7,2
9,1–10,0	1	50,0					2	10,6	6	28,6	2	11,1	11	6,1
10,1–11,0							1	5,3	4	19,0	2	11,1	7	3,9
11,1–12,0			2	14,3					2	9,5	3	16,7	7	3,9
12,1–13,0			1	7,2					1	4,8	2	11,1	4	2,2
13,1–14,0											4	22,2	4	2,2
14,1–15,0			1	7,2							3	16,7	4	2,2
17,1–18,0									1	4,8			1	0,6
22,1–23,0									1	4,8			1	0,6

larvae were encountered. Isolated individuals were collected inshore between Palgrave Point and Sandwich Harbour, the length range extending between 4,10 mm and 23,00 mm and the mean length showing a gradual increase from month to month. No larvae were taken in the plankton during February or March/April.

Influence of hydrology on seasonal occurrence of larvae

The seasonal hydrological features for both survey periods have been described by O'Toole (1977). For the purpose of this report, the general sequence of events can be readily distinguished by the monthly distribution of surface isotherms shown on the larval distribution charts in Figures 6 and 7. It is apparent that larvae of *A. microlepis* occurred mainly in the zone of active upwelling between Cape Cross and Hollams Bird Island and particularly when upwelling was most intense (i.e. late winter and spring). Hydrological conditions during the spawning season showed that cold, low-salinity water was widespread along the coast. Temperature and salinity were generally uniform with depth, indicating a well-mixed water layer. Towards summer, upwelling decreased gradually and warm, saline water advanced inshore, leading to more stable conditions and a corresponding decrease in the number of larvae.

Larvae of the West Coast sole were found at surface temperatures ranging from 11,4°C to 19,8°C. Nevertheless, approximately 74 per cent of all hauls containing larvae were made when temperatures were between 12,1°C and 16,0°C. Of the remaining positive hauls, 23 per cent were taken at temperatures greater than 16,0°C and three per cent at temperatures lower than 12,0°C. The abundance of larvae in relation to surface temperature is summarized in Table VII.

Planktonic fish larvae generally inhabit the upper 50 m of water (Ahlstrom 1959) but may become stratified at certain depth levels depending upon biological and physical factors. The depth distribution of *A. microlepis* larvae was not investigated during this study and consequently the larvae may have occurred at a variety of temperatures within the 0–50 m layer. However, depth profiles showed that temperature was usually uniform to 50 m, especially during the upwelling months when larvae were most abundant. It is therefore likely that the optimum surface temperature range reflects to within one degree the thermal conditions in the water column.

Larvae of the West Coast sole were found over a narrow surface salinity range of between 34,91‰ and 35,30‰. Approximately 84 per cent of all positive hauls were made at salinities of 35,01–35,20‰. Only 9,1 per cent of hauls containing larvae were made at surface salinities less than 35,00‰, and 6,1 per cent at salinities greater than 35,20‰. The 10 largest hauls of larvae were taken at salinities of 34,91‰ to 35,20‰ (Table VIII) with eight of the hauls occurring in the 35,01–35,20‰ range.

DISCUSSION

The coastal water between Cape Cross and Hollams Bird Island is an important spawning location of the West Coast sole *A. microlepis*. The abundance and the length composition of the larvae indicate a relatively short spawning season from early spring until early summer, larval abundance rapidly decreasing thereafter.

Table VII: Relationship between surface temperature and number of hauls containing West Coast sole larvae

Surface temperature (°C)	Number of hauls			
	1–10 larvae	11–50 larvae	more than 50 larvae	Total
11,1–12,0	1	2	0	3
12,1–13,0	6	5	0	11
13,1–14,0	14	12	5	27
14,1–15,0	9	5	2	16
15,1–16,0	9	4	2	15
16,1–17,0	5	3	1	9
17,1–18,0	3	1	0	4
18,1–19,0	1	3	0	4
19,1–20,0	3	1	0	4

Table VIII: Relationship between surface salinity and number of hauls containing larvae of the West Coast sole

Surface salinity (‰)	Number of hauls			
	1–10 larvae	11–50 larvae	More than 50 larvae	Total
34,91–35,00	5	2	2	9
35,01–35,10	18	19	5	42
35,11–35,20	25	13	3	41
35,21–35,30	5	1	0	6

Spawning was generally confined to upwelling areas within 30 km of the shore and was apparently heaviest in the vicinity of Conception Bay and Hollams Bird Island and between Cape Cross and Walvis Bay.

The northern limit of larval distribution suggested that little spawning took place north of Palgrave Point. This does not totally agree with the distribution of commercial catches over the past few years. Since 1970, when demersal-fish research commenced in South West Africa, the sole catches have predominantly come from the area between Rocky Point (19°S) and Palgrave Point. This was particularly evident during the peak years for sole (1971 to 1974), during which period this larval research was conducted (A. I. L. Payne, Sea Fisheries Branch, personal communication). Only a small portion of the sole landings resulted from fishing in the more extensive grounds south of Walvis Bay. This was probably because the sole population was more scattered on these offshore grounds to which fishing was legally restricted. As sexually active fish were recorded from the northern grounds (A. I. L. Payne, Sea Fisheries Branch, personal communication), the result of spawning north of Palgrave Point should have been noted in the collections of larvae. The complete absence of any West Coast sole larvae in the north during the months of the survey indicates that further research is necessary to finalize the whole mechanism of egg and larval dispersal of this species.

The southern extension of spawning was not delineated, which implied that some spawning took place to the south of Hollams Bird Island. Because no collections were taken from April to July 1973 (mid-autumn to midwinter) or after April 1974, the duration of the spawning season could not be strictly determined. The fact, however, that larvae suddenly appeared in the plankton in early spring and disappeared in early summer suggested that spawning was probably insignificant at other times of the year.

Newly hatched larvae were more numerous and widespread during the 1972/73 survey, suggesting that spawning was more intense and took place over a greater area during that season than in 1973/74. During the first survey, peak spawning occurred in early September and early November. In contrast, the breeding area was geographically more restricted during the second survey, with peak spawning taking place in early October. An earlier decline in upwelling during the 1973/74 spawning season could have resulted in that season being shorter (compare October and November of both years, Figs. 6 and 7). However, since the number of West Coast sole larvae captured during the surveys was relatively small compared with other pelagic fish larvae (O'Toole 1977), patchiness in distribution, diurnal migration or gear inadequacies may have caused the apparent variation in larval abundance between years.

The pelagic eggs and the developing larvae of the West Coast sole should drift northwards along the coast from the southern spawning grounds. Although the direction of water movement was not monitored during the routine ichthyoplankton surveys, the seasonal distribution of temperature and salinity confirms the general trends outlined by Hart and Currie (1960). The flow is usually northerly in winter and spring, when the prevailing south and southwest winds are strong and upwelling is intense. Isotherms are characteristically orientated parallel to the coast, especially in the south where upwelling is strongest. In summer, when the prevailing winds weaken, upwelling is reduced and warm oceanic water tends to move southwards and inshore.

A typically northward transportation is shown by comparing the distributions of size categories of larvae in September and October 1972 (Figs. 8 and 9). This period was selected because the cohort could be easily traced from the one month to the other. During September, newly hatched larvae (those less than 4,00 mm long)

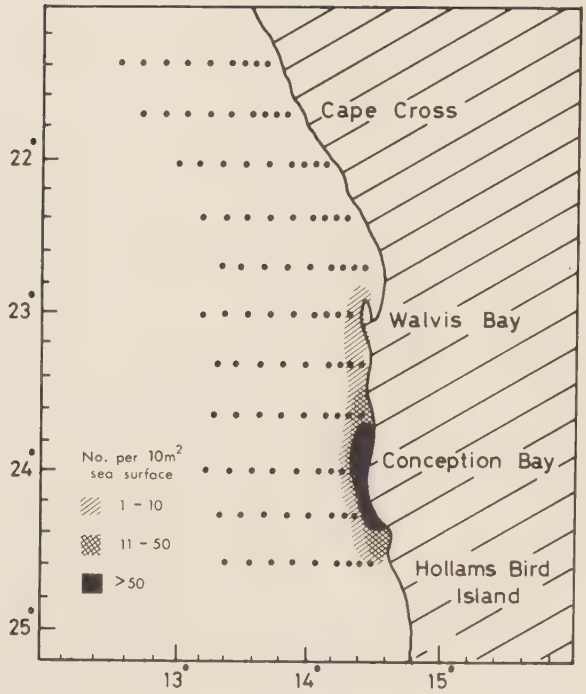

Fig. 8: September 1972 – Distribution and abundance of West Coast sole larvae shorter than 4 mm

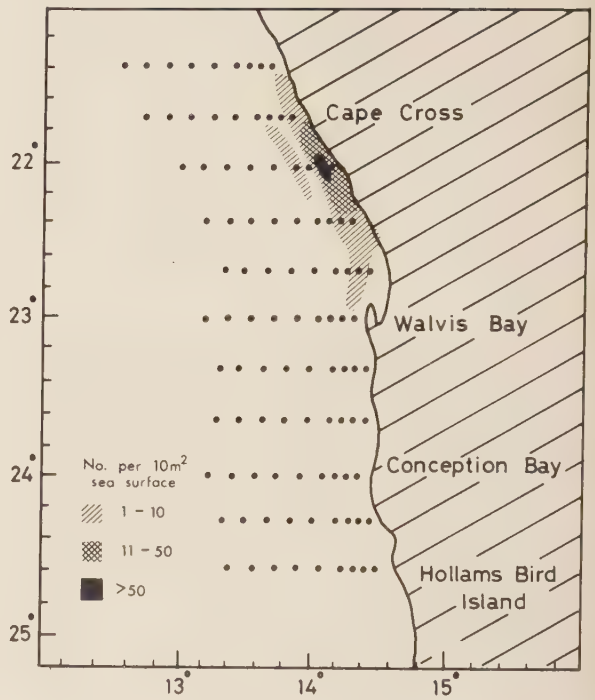

Fig. 9: October 1972 – Distribution and abundance of West Coast sole larvae longer than 8 mm

were abundant in the inshore waters between Walvis Bay and Hollams Bird Island (Fig. 8). Maximum numbers occurred off Conception Bay. In October, larger larvae (those longer than 8,00 mm) although less numerous, were found between Cape Cross and Walvis Bay, peak concentrations being off Cape Cross (Fig. 9). If the more advanced stages collected in October represented some of the newly hatched larvae taken in September, then the population was transported northwards 160–180 km in a period of about 30 days and showed a growth of between 5,00 mm and 6,00 mm.

A laboratory-reared West Coast sole larva completed the yolk-sac stage in eight days at 15°C (C. Brownell, University of Cape Town, personal communication) thus indicating that the pelagic phase of the larva lasts approximately 38 days. The fact that 74 per cent of the larvae in this study were taken at temperatures between 12,1°C and 16,0°C appears to confirm that 35–40 days of pelagic development precedes the adoption of the demersal habitat.

During metamorphosis, the percentage frequency of large larvae taken in the catches decreased rapidly (Tables IV and VI), probably as a result of the developing juveniles descending to deeper layers.

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INFLUENCE OF SOME HYDROLOGICAL FACTORS ON THE DEPTH DISTRIBUTION OF MAASBANKER (*TRACHURUS TRACHURUS*) LARVAE OFF SOUTH WEST AFRICA

M. J. O'TOOLE

The maasbanker or horse mackerel, *Trachurus trachurus* L., forms an important pelagic, mid-water and demersal fish resource in the south-east Atlantic. The fishery for this species off South West Africa, although relatively recent, is becoming increasingly valuable. Stocks are being exploited mainly by vessels of the Soviet Union and South West Africa. Landings, excluding those of Angola, have fluctuated between approximately 63 000 metric tons in 1968 and 250 000 metric tons in 1974.

The Sea Fisheries Branch has been engaged in quantitative egg and larva surveys since 1971 as one method of stock assessment within the framework of the Cape Cross Programme (Cram and Visser 1972). Variation in the vertical distribution of fish larvae makes it difficult to estimate species abundance reliably from extensive ichthyoplankton collections. Such estimates would demand as a prerequisite a knowledge of the vertical distribution of the species during its larval phase. Furthermore, knowledge of the effects of biotic and abiotic factors on the depth distribution of the larvae would be useful in larval survival and recruitment studies.

Larvae of the maasbanker were found to be both abundant and widespread in plankton samples taken during a two-year egg and larva survey off South West Africa (O'Toole 1974). Little is known about the depth distribution of maasbanker larvae in relation to environmental conditions in the region. The only known observation was by d'Arcangues (University of Paris, personal communication) during an investigation of the scattering layer off the coast in February 1974. Several larvae were then taken at depths ranging from 14 m to 70 m at temperatures of 14 – 16°C.

At 12h00 on 2 January 1975, during a routine ichthyoplankton cruise by the R. S. *Benguela*, large numbers of maasbanker larvae were located approximately 40 km west of Palgrave Point (Fig. 1). The surface temperature ranged from 20,0°C to 20,3°C. Samples were collected simultaneously at a series of depths, using nine samplers similar to those described by Miller (1961). The samplers consisted of 14,0-cm diameter PVC tubes with 0,50-mm mesh conical collecting nets and were spaced at intervals of 10 m along the towing cable. Bathykymographs were positioned at 30 m and 60 m to provide depth profiles of the tow. A V-fin depressor (57 kg) was used to submerge and stabilize the samplers during the haul. The nets were towed at about two knots for a period of one hour in a westerly direction.

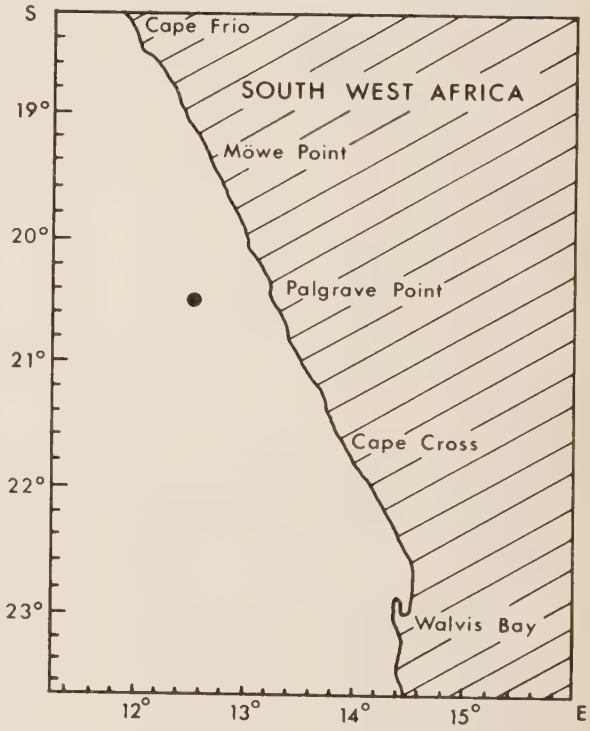

Fig. 1: Location of capture of maasbanker larvae

Larvae were extracted from the samples, counted and measured to the nearest tenth of a millimetre. The mean depth fished by each net was established by interpolation of the bathykymograph traces. Temperature, salinity, dissolved oxygen and total chlorophyll measurements were

taken at selected depth intervals at the beginning and the end of the tow.

No larvae were taken in the upper 12 m of water. One hundred and thirty larvae, ranging in size from 2,5 mm to 7,8 mm were captured within the depth range 18–75 m. Correlation of hydrological observations and larval abundance with depth is given in Table 1. Approximately 50 per cent of all the larvae were found near the thermocline at a depth of 25 m and a temperature of 18,2°C. Numbers fell off below the thermocline. Larvae occurred over the following range of environmental parameters:

Temperature 13,5 – 19,1°C
Salinity 35,20 – 35,45‰
Oxygen 4,6 – 5,0 ml/l.

Table I: Depth distribution, abundance and size of *Trachurus trachurus* larvae in relation to hydrological parameters

Mean depth (m)	Hydrology				Larvae			
	Temperature (°C)	Salinity (‰)	Oxygen (ml/l)	Chlorophyll (ml/l³)	Number of larvae	Length range (mm)	Percentage shorter than 4,0 mm	Percentage longer than 4,0 mm
0	20,3	35,52	5,3	2,5	—			
8	20,0	35,50	5,2	2,8	—			
12	19,9	35,48	5,1	3,2	—			
18	19,1	35,45	5,0	4,6	18	3,5–7,8	22,2	77,8
25	18,2	35,32	4,9	5,8	64	2,5–6,9	40,6	59,4
44	16,3	35,25	4,6	5,0	24	3,9–5,8	25,0	75,0
53	15,2	35,25	no data	3,1	16	3,2–7,4	11,0	89,0
62	14,0	35,20	no data	2,1	4	5,0–6,5	0	100,0
75	13,5	no data	no data	2,3	4	4,0–5,2	0	100,0

However, since the entire depth distribution of the larvae was not covered, these ranges of parameters should not be regarded as limiting for maasbanker larvae.

The observed vertical distribution of larvae compares favourably with that of related species of *Trachurus*. Ahlstrom (1959) noted that about 80 per cent of *T. symmetricus* larvae occurred in the upper 50 m but that the centre of abundance fluctuated between 10 m and 44 m. The optimum depth of larvae of *T. japonicus* was found to be 20 m (Ida 1972).

During this investigation, no differences in the depth distributions of larval classes were found except that more than 60 per cent of recently hatched specimens (2,5 – 4,0 mm) occurred near the chlorophyll maximum layer. Although the results are based on only one set of observations, it is possible that these early larval stages were actively feeding in this layer at the time of capture. If this assumption is correct, then the vertical displacement or the destruction of the chlorophyll maximum layer may significantly influence the depth distribution and survival of newly hatched larvae.

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